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THE

ANATOMY AND SURGERY

OF THE

FRONTAL SINUS AND ANTERIOR ETHMOIDAL CELLS.

BY

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METHOD OF INVESTIGATION.

This opportunity is taken to express my great indebtedness to Professor Thomas Dwight, of Harvard University, not only for the unlimited privileges necessary to carry on this investigation, but also for many valuable suggestions.

About 125 subjects, or 250 frontal sinuses, obtained from dissecting-room material, form the basis of this research. They were inspected when obtained, and preserved in alcohol for future study and reference.

Fifty of these specimens were macerated, after examination, in the natural state, and about fifty more bony specimens have been accessible for study.

The parts have been examined from sagittal, coronal, and horizontal sections, and also by dissection of especial regions, the use of probes, injection of fluids, etc.

The accompanying plates were made from photographs taken by Bernard W. Trafford, Esq., of Boston, whose assistance and skill were invaluable in adding to the success of the work. These photographs were taken from specimens selected as seemed necessary to demonstrate the anatomy under consideration, hence the relations are an exact reproduction. The size of the specimen reproduced in the plate is not altered, except in a few obvious instances.

The aim of the anatomical portion of this paper is not to describe accurately and completely any one or more bones, but only the necessary portion of any bone entering into the topography of the region to be considered.

PART I.

A STUDY OF THE ANATOMY OF THE FRONTAL SINUS AND ANTERIOR ETHMOIDAL CELLS.[1]

The Frontal Sinus.

The frontal sinuses are two cavities situated, for the greater part, in the frontal bone, one on either side of the median line, and anterior to the ethmoidal notch. No matter how small the sinuses may be, they will be found at the antero-internal junction of the horizontal (orbital) and vertical (squamous) portions of the frontal bone, just internal to the internal angular process. (Plate 1.) Thence, according to their development, they may extend for a variable distance between the laminæ of these portions of the frontal bone, as will be described in detail.

Each sinus may be considered as the space formed by the intersection of four planes, and assumes roughly the form of a three-sided pyramid, and presents the following points for examination: Three surfaces—anterior, posterior, internal—and a base,—inferior surface. (Plates 20, 53, 54, 56, 60.) All surfaces are roughly triangular. Of the several borders, three deserve particular mention,—anterior, superior, and posterior. Three angles are prominent,—superior, external, and posterior.

Anterior Surface.—The anterior surface is situated entirely in the vertical portion of the frontal bone, and is bounded below by the supraorbital arch (Plate 1), internally

[1] This work was awarded the Warren Triennial Prize for the year 1898, by the physicians and surgeons of the Massachusetts General Hospital.

by the median line, generally represented by a partial suture at its lower part, but the superior limit of this surface is very variable, and has no external landmark. The surface as a whole is somewhat convex from side to side, and more so vertically, on account of the superciliary ridges which traverse it from below upward and outward, and serve, to a certain extent only, as a guide to the location and size of the sinus. The superciliary ridges meet in front at the nasal eminence or glabella, which is a useful landmark for the surgeon. The surface, as a whole, is rather smooth and covered with minute foramina, leading to cancellated tissue. This is the thickest of the four surfaces, and varies from one millimetre to six millimetres in thickness in different places, according to age, sex, and race, although about two millimetres to three millimetres would be a fair average. This sinus wall is apt to be thicker in the vicinity of its boundaries and at the most prominent part of the superciliary ridge.

The anterior surface measures the height and width of the frontal sinus, and is consequently very variable. Laterally, the sinus may extend only occasionally to the external angular process of the frontal bone. An average of 200 sinuses, measured from the median line laterally, lie between two centimetres and two and eight-tenths centimetres, and this shows that it is not safe to trephine for the sinus external to the supraorbital notch or foramen. The height of the sinus is given as the measure of the internal border of the anterior surface, close to the internal surface, from the base to the apex of the pyramid. This will average one and eight-tenths centimetres to two and one-half centimetres, and this is usually the highest point of the sinus.

Above the superciliary ridge the smooth surface of bone is uninterrupted, but below we come to the sharp supraorbital arch, thick and generally notched, which terminates at the internal angular process of the frontal bone. The lower border of this surface is then fixed by the suture between the frontal bone, on the one hand, and the nasal bone and the nasal process of the superior maxillary bone, on the other

hand. Where the nasal eminence is very prominent the lower portion of the anterior surface looks somewhat downward as well as forward. (See plates of sagittal sections.)

Anterior to this surface of the frontal bone are certain facial muscles, supraorbital and frontal arteries, and supraorbital and supratrochlear nerves, all directly under the skin, which is loosely connected to the deeper parts by the superficial fascia. None of these structures should offer any hinderance to the surgeon in making any incision whatever over the region of the frontal sinus.

Posterior Surface. (Plates 51, 53, 60, 67, sagittal sections.)—The posterior surface belongs in part to both the vertical and horizontal portions of the frontal bone, and is much thinner than the anterior surface. The vertical portion is somewhat convex towards the sinus, as is also the horizontal portion, if the sinus is small, but where the sinus extends laterally between the laminæ of the orbital portion (Plates 65, 71), then this posterior surface of the sinus becomes concave in conformity with the general arch of the roof of the orbit. Posteriorly this surface forms part of the wall of the anterior cranial fossa, and is in contact with the frontal lobe of the brain and along its inner border with the olfactory lobe. Just anterior to the ethmoidal notch the two posterior surfaces come together in the median line, forming with the ala processes of the ethmoid bone the foramen cæcum, whence ascends the frontal crest. (Plate 57.) The upper and outer boundaries of the posterior surface of the frontal sinus, as viewed from within the skull, are not defined, but the internal border, moreover, follows the frontal crest as far as the foramen cæcum, is reflected around the crista galli, and then follows the lateral border of the cribriform plate (lamina cribrosa). (Plates 16, 17, 76.) The posterior surface of the frontal sinus becomes horizontal in its orbital portion, and is continued as the roof of the anterior and then the posterior ethmoidal cells. (Plates 51, 77.)

This posterior wall of the frontal sinus is dense and brittle, and contains no diploe, but sections of the anterior wall

often show more or less cellular structure between two layers of more dense bone. (Plate 10.) As compared with the posterior wall, the anterior is tougher and more likely, up to a given point, to bend them to fracture. Sections of the vertical portion of the frontal bone show that the diploe ceases rather abruptly (Plates 5, 9) at the junction of the posterior and anterior surfaces (superior border), although, as just mentioned, the anterior surface is somewhat cancellated. If the vertical portion of the frontal sinus is wanting, the two lamellæ of bone are more nearly approximated, and the intervening space filled with cancellated bone. Hence a careful operator would observe the presence of this diploe, in case the sinus was not developed, and avoid entering the cranial cavity. (Plates 3, 4.)

Internal Surface.—Situated between the two sinuses is a thin lamina of bone, easily perforated by a sharp-pointed instrument, either side of which serves as the internal surface of its corresponding sinus. The inferior border of this septum is usually near the median line, and is continuous with the plane of the crista galli, the perpendicular plate of the ethmoid, and the nasal spine of the frontal bone. This border is considerably thickened, passes off laterally to form a dense portion of the inferior surface or base of the sinus, and is continued below in the median line at the nasal spine. (Plates 9, 13, 56, 60, 62, 76.)

In the majority of cases this septum deviates to one side or the other within a range of five millimetres, or even more, notwithstanding its frequent median position inferiorly. Its surface is usually convex near its centre, with a corresponding concavity on the other side, unless, as occasionally happens, the septum is very thick and the sinuses are small, then both surfaces are concave. (Plate 64.) The sinuses become divergent towards their apices, so that the upper portion of the septum is much thicker than its centre.

The plane of the septum is roughly antero-posterior, passing between the anterior and posterior surfaces, but occasionally it may be so deviated that one sinus lies partly

overlapping the other, even to an extent of two centimetres. This is a point of obvious surgical importance. With remarkable constancy, on account of its often delicate structure, this septum is usually complete, so that there is no communication between the sinuses. An examination of 180 specimens has revealed two examples, one an oval perforation near the centre of the septum, the other, its almost entire absence. (Plate 55.)

Inferior Surface (floor or base of the sinus). (Plates 13, 15, 16, 57, 61, 65, 71.)—The inferior surface is divisible into an orbital and a nasal portion.

The orbital portion lies external to the nasal portion, enters into the formation of a part of the roof of the orbital fossa, and its extent is open to considerable variation according to the size of the sinus. Its surface is markedly convex laterally towards the sinus, and but slightly so in the antero-posterior direction. (Plate 54.) It is triangular, limited in front by the supraorbital arch, internally by the suture between the frontal bone, on the one hand, and the os planum (lamina papyracea) of the ethmoid bone and the superior border of the lachrymal bone, on the other. (Plates 5, 20.) There is nothing on the roof of the orbit to indicate its posterior extent. This layer of bone forming the orbital portion of the floor of the sinus is the inferior of the two laminæ into which the orbital portion of the frontal bone divides as it approaches the ethmoidal notch; the superior lamina, moreover, goes to complete a portion of the posterior surface of the sinus. The outer portion of this inferior lamina is nearly horizontal, but as it approaches the median line it turns a sharp angle downward so as to be vertical at its termination. (Plate 20.) The under surface is smooth and marked anteriorly by a slight depression or small tubercle of bone for the cartilaginous pulley of the superior oblique muscle. (Plate 13.) The sinus aspect of this lamina is likewise smooth, but is frequently roughened by the presence of septa connected with the sinus or anterior ethmoidal cells, to be described in detail later.

In front, this surface usually extends laterally a little beyond the supraorbital notch, frequently one centimetre farther, and occasionally as far as the external angular process of the frontal bone. (Plate 71.) Posteriorly its inner border frequently reaches the anterior ethmoidal foramen (Plate 5), and in rare instances it may nearly approach the lesser wing of the sphenoid bone. Such a sinus would be very large. With the exception of the thin walls of the ethmoidal cells, which in part complete the nasal portion of the floor of the sinus (Plate 16), the orbital portion is the thinnest of all the sinus walls. This is evident, not only from inspection of the bone, but also from the result of pathological changes consequent on obstruction of the ostium frontale.

Internally the plane of the inferior orbital lamella is continuous with the lachrymal bone and the os planum of the ethmoid, so as to form the internal boundary of the orbital fossa, and the external boundary of the lateral mass of the ethmoid bone (Plate 20), indeed, from a surgical point of view a portion of the lateral boundary of the nasal fossa. This general curvature must be constantly kept in mind by the operator when entering the sinus or anterior ethmoidal cells from in front. Although not mathematically constant, the general curvature is so regular, and its direction and contour so uniform, that this lamella serves as the guide for the surgeon in avoiding the orbital fossa.

The nasal portion of the inferior surface or floor of the sinus is somewhat complicated, but a thorough understanding of its composition and relations is of great surgical importance. It is a comparatively small surface, and well defined only in selected cases. Its surface is very uneven and interrupted by the rounded eminences of ethmoidal cells, bony septa from different directions, and the presence of a foramen of varying size and shape which leads into the nasal fossa. (Plates 15, 16, 17.) These features may almost obscure the surface, particularly behind, where it passes into the posterior angle of the sinus. It is a surface of greater sur-

gical than anatomical importance, hence its consideration will be dwelt upon at length.

In general, by the nasal portion of the floor of the frontal sinus we mean the irregular, somewhat horizontal surface which separates the sinus from certain ethmoidal cells and other portions of the ethmoid bone, internal and at right angles to the plane of the lachrymal bone and os planum. (Plates 20, 72, 76, 79.) It terminates in front, at the line of suture, between the frontal bone and the nasal process of the superior maxilla, externally it joins the orbital lamina of the frontal bone, internally it does not reach the septum nasi in the median line, but is arrested at the line of junction of the internal wall of the lateral mass of the ethmoid with the cribriform plate of the same. (Plates 13, 17, 79.) This internal wall of the lateral mass is the upward prolongation of the lower ethmoidal turbinate (commonly called the "middle turbinate"), and is carried forward so as to continue the internal boundary of the nasal portion of the floor of the sinus by articulating with the ethmoidal crest of the superior maxilla. (Plates 2, 3.) This internal border of the nasal portion of the floor is completed in front by a small portion of the thickened frontal septum as it is continued into the nasal spine. (Plates 11, 15.) Posteriorly the nasal portion of the floor is lost in the posterior angle of the sinus. (Plate 76.)

On viewing the under surface of the frontal bone, an irregular opening is observed which leads to the right or left frontal sinus respectively, and is known as the hiatus frontalis. (Plates 13, 15.) Following the circumference of the hiatus frontalis, we have in front the articulation of the nasal process of the superior maxilla, externally the lachrymal bone and os planum along the free edge of the inferior orbital lamella, internally the frontal septum, behind which we come to the ethmoidal notch formed by the two superior orbital laminæ. (Plates 14, 15, 16.) Hence, between these two orbital laminæ in front is an opening, the hiatus frontalis, while posteriorly the intervening space is interrupted by septa forming cavities which help to complete certain of the an-

terior and posterior ethmoidal cells when the frontal bone is *in situ*. (Plate 13.) This inferior aspect of the hiatus frontalis, and the area immediately posterior to it, gives one the best idea of what is meant by the nasal portion of the floor of the frontal sinus. The ethmoidal notch is filled by the cribriform plate, whence descends in the median line the perpendicular plate of the ethmoid bone (lamina perpendicularis). The cribriform plate forms a portion of the true anatomical roof of the nasal fossa, is internal to the hiatus frontalis and apices of ethmoidal cells (Plates 16, 17), roughly parallel with the nasal surface of the frontal sinus, yet on a little higher plane. Again, looking at the inferior surface of a frontal bone (Plate 13) with the cribriform and perpendicular plates in position, we have a space averaging from one centimetre to one and eight-tenths centimetres wide between the free edge of the inferior frontal lamina to the lamina perpendicularis. This space is divided by a third parallel lamina, which is simply the upward continuation of the inferior ethmoidal turbinate to its insertion on the lamina cribrosa, and its anterior prolongation to the ethmoidal crest of the superior maxilla. The outer space is occupied by the nasal floor of the frontal sinus in front, behind by the anterior ethmoidal cells. (Plates 20, 58, 62, 65, 74, 77, 79.) The internal space, somewhat narrower, is roofed over by the lamina cribrosa, and, although a dangerous locality, this additional space is of value in the operative treatment of diseases of the frontal sinus and anterior ethmoidal cells.

Further consideration of the floor of the nasal portion of the frontal sinus must be deferred until a portion of the ethmoid bone has been described.

The anterior border of the frontal sinus is formed by the junction of the anterior and inferior surfaces, and follows the line of the supraorbital arch. (Plates 1, 53.) These surfaces meet at an angle somewhat greater than 90 degrees, so that this border is rounded rather than sharply defined.

The superior border follows the line of union of the superior and posterior surfaces, which usually meet at a

rather acute angle, so that this border is well marked. (Plates 51, 54.)

The posterior border follows the line of separation of the orbital laminæ as they diverge to become the inferior and posterior surfaces of the sinus. Towards the external angle this border is usually unobstructed (Plate 54), but, as it approaches the internal angle (Plate 53), the narrow space between the orbital laminæ is filled up with one or more bony cells of variable size, which protrude forward into the sinus so as to diminish its size, often to a considerable degree. These cells, together with those at the posterior angle, are so intimately associated with the anterior ethmoidal cells that they will call for a more detailed account later.

The superior angle is the apex of the sinus, lies in the vertical portion of the frontal bone, and offers nothing of particular interest.

The external angle is sharp and corresponds to the most lateral portion of the sinus. Its location, like that of the superior angle, varies according to the size of the sinus.

The posterior angle is usually filled with cells and is of much surgical importance. It will be better understood in connection with the nasal floor of the sinus and the anterior ethmoidal cells.

Other borders and angles exist which call for no particular mention.

General Considerations.

External Appearances.—There are no absolutely certain guides by which the degree of development of the frontal sinuses in the adult can be determined before attempting to expose them. At birth, the frontal bone is in two portions, the sinus has not yet appeared, and the frontal eminences are prominent. As the child grows the sinuses develop slowly and the general shape of the head and frontal region changes. At puberty, the sinuses are practically developed and the frontal area has assumed its adult form. The gradual appearance of the superciliary ridges, which are apt to be most

marked over the sinuses and the nasal eminence, make the supraorbital area of the adult more prominent, and the frontal eminences less so when contrasted. In general, it is fair to conclude that the more prominent the supraorbital area, including both the superciliary ridges and nasal eminence, the greater the probability of the presence of well-defined sinuses. (Plates of sagittal sections.) Even fairly well-marked superciliary ridges on a non-protruding supraorbital area are frequently accompanied by poorly developed sinuses or even absence of their vertical portion. (Plate 6.)

Race characteristics have some influence, as shown by poor sinus development in receding frontal bones.

Sinuses in the male appear to be relatively larger than would seem to be warranted by the usual disproportion between the measurements of the bones in general of the male and female skeleton. This may be but a part of the general accentuation of eminences and depressions in the male sex, particularly in the vicinity of joints.

Transillumination of the unopened sinus on the cadaver after the removal of the calvarium, transmitting the light from below towards the cranial cavity, is a good guide for determining, approximately, both the size of the sinus, its presence or absence, and the thickness of the walls. The value of transillumination in determining these points and also the presence of exudate within the sinus in practice will be considered in Part II.

The relative thickness of the sinus walls has been considered, but the actual thickness is influenced more or less by age, sex, and race. The walls are somewhat thicker in the male, where the bones in general are heavier, and in races characterized by well-developed bones. Bones of the aged may lose a third of their weight by absorption, whereby bony laminæ become much thinner and more brittle. The size of the sinus may be thereby somewhat increased, but to no very appreciable extent.

Occurrence.—With very great regularity both sinuses are present. Several anatomists are authority for the statement

that one or both sinuses may be absent without indicating whether the whole sinus or its vertical portion was meant.

A sagittal section, made so as to pass through the nasal portion of the inferior surface, shows that the sinus, as a whole, is flattened from before backward, and curved upon itself so as to present an anterior convexity. (Plates 9, 51, 52.) The superior part of the sinus lies within the vertical portion of the frontal bone, the posterior part is in the orbital portion, and the most prominent part of the convexity is at the anterior border, which follows the line of the supraorbital arch. (Plates 10, 11, 36.)

An examination of about 250 sinuses has given these results:

(1) That in no instance has the orbital portion been wanting, although it may be much diminished in size, and correspond to an anterior ethmoidal cell. There has always been an orbital space communicating with the middle meatus, either indirectly through the infundibulum, or directly by an ostium under the anterior line of insertion of the lower ethmoidal turbinate, in conformity with one of the usual modes of communication between the nose and frontal sinus.

(2) That in about 3 per cent. of the cases the frontal sinus does not reach to the vertical portion of the frontal bone, at least on one side. From a surgical stand-point such a sinus may be said to be wanting, for the diagnosis and treatment of suppuration in a small orbital sinus would not differ materially from such a condition present in the anterior ethmoidal cells.

(3) That a sinus may be of ordinary size on one side and abortive on the other. (Plate 63.)

(4) That the sinuses of the two sides are never precisely alike.

(5) That the sinus of each side opened into the corresponding nasal cavity, with one exception.

(6) That in one case the frontal sinuses were of more than average size; that there was no trace of a median septum except a slightly elevated ridge corresponding to its

periphery; that on the left side of the median line there was no ostium frontale, but on the right side there was one ostium frontale in the usual location, serving as an outlet for this large common sinus into the right nasal cavity. This abnormal condition will be described later. (Plate 55.) The pyramidal shape of the sinus can be made out in most cases (Plate 53), but it may be obscured, however, from several causes. The borders may be more than ordinarily rounded and the angles cut off by protruding cells or excess of diploe. Thus the sinus may appear as a small oval cavity. (Plates 5, 49, 50.)

Septa.—Wherever the sinus is of large size it is usually the rule to observe bony septa, passing most commonly between the anterior and posterior surfaces. (Plates 10, 11, 20, 55, 56.) They may be apparently complete or partial, so as to subdivide the sinus into smaller cavities. Where the septum is nearly complete the communicating foramen is usually towards the posterior border or posterior angle. The plane of the septa is most commonly rather vertically placed and running in a general antero-posterior direction, often radiating from the posterior angle. Partial septa are often of considerable thickness, and are more commonly found at the superior and anterior borders, whereas the posterior border and angle are filled with cells. Septa are easily broken down with the curette or bone forceps. They give additional strength to the walls of the sinus.

Occasionally pockets lead from the inferior portion of the sinus, thereby rendering this surface still more irregular. The nasal process (Plates 32, 37) may be thus hollowed out, and less frequently the crista galli of the ethmoid bone (Plate 26) may be only a shell containing a diverticulum from a frontal sinus. More frequently a diverticulum pushes directly downward into the space bounded externally by the lachrymal bone, internally by the upper extremity of the uncinate process of the ethmoid, and in front by nasal process of the superior maxilla. (Plates 51, 52.)

Defects in the continuity of the frontal sinus walls, de-

scribed as dehiscences (Zuckerkandl), must be very unusual. None have been detected in this series of 250 sinuses. They are said to occur near the front of the fronto-nasal suture. Several instances of orbital dehiscences, however, associated with the anterior ethmoidal cells have been noted; these will be considered later.

Ethmoid Bone.—Such parts only of this bone will be considered as are concerned in the regional anatomy of the frontal sinus and anterior ethmoidal cells.

Lamina Cribrosa (Plates 13, 16, 17, 18, 72, 76).—The horizontal or cribriform plate (lamina cribrosa) is rectangular in shape and fills in the ethmoidal notch (Plate 15) of the frontal bone articulating on three borders with the *superior* lamina only of the orbital portion of the frontal bone. The posterior border is notched for the reception of the ethmoidal spine of the sphenoid bone. The plate is bisected by the plane of the crista galli and hollowed out for the reception of the olfactory lobes. On each side of the median line are three parallel rows of foramina for the transmission of the olfactory nerves. The foramina of the inner row are the largest, and lead to grooves on the lamina perpendicularis of the ethmoid (Plate 28); those of the median row are the smallest; and those of the outer row are intermediate in size, and lead to grooves on the inner side of the internal wall of the lateral mass. (Plates 2, 3.) Close inspection shows that the larger foramina are merely depressions, at the base of which are seen several minute openings. Anteriorly, quite close to either side of the crista galli, is a slit-like foramen for the passage of the nasal branch of the ophthalmic division of the fifth cranial nerve.

Viewed from above, the cribriform plate will be seen to be occasionally much obscured by the conformity of the orbital plate or by a wide crista galli.

Lamina Perpendicularis (Plates 20, 21).—Descending from the median line of the lamina cribrosa is the lamina perpendicularis which completes the greater portion of the upper part of the nasal septum. It is a somewhat quadrangu-

lar section of bone, thinner in the centre than at the periphery. The superior border is attached to the cribriform plate, and terminates at the anterior extremity of this plate.

The anterior border, two centimetres to three centimetres long, runs downward and forward, articulating above with the nasal process of the frontal bone and near its extremity with the crest of the nasal bones. (Plates 19, 26.) The plane of the lamina perpendicularis is usually concave to one side or the other, and its surface grooved vertically for nasal nerves.

Crista Galli.—In the same median plane, but situated above and on the anterior portion of the lamina cribrosa, is a prominent triangular crest of bone called the crista galli. On each side of its anterior border is a process (processus alaris) which helps complete the foramen cæcum when articulated with the frontal bone. The crista galli lies behind and occasionally above the septum, between the frontal sinuses, and generally in close proximity. (See sagittal sections.) It may be thin and dense, or wide and cancellated; its anterior border may be free or closely associated with the posterior surface of the frontal sinus, and in exceptional cases it may be hollow and form a portion of the sinus itself,—crista galli diverticulum. (Plates 10, 26.)

Lateral Masses. Ethmoidal Labyrinth (Plates 17, 18, 19, 20, 21).—The lateral masses of the ethmoid bone are two irregular bony structures, one suspended on either side of the lamina perpendicularis from the lamina cribrosa. Each lateral mass presents an inner and an outer wall, between which is an intricate cellular net-work, called the ethmoidal labyrinth.

The outer wall consists of a thin, rectangular lamina of bone, called the os planum (lamina papyracea), which forms a portion of the inner wall of the orbital fossa. (Plate 9.) When the ethmoid bone is disarticulated, the os planum is surrounded on all sides by a series of seemingly broken cellular spaces (Plate 19), but in the natural state these cells are completed by neighboring bones. The superior border of

the os planum articulates with the *inferior* lamella of the orbital portion of the frontal bone, so that, obviously, the broken cellular spaces between this border and the cribriform plate are completed by corresponding spaces between the orbital laminæ. Hence, superiorly the ethmoid cells are partially within the frontal bone. (Plates 13, 14.) The ethmoidal foramina are at either extremity of this suture, the anterior of which will concern us later.

The anterior border of the os planum articulates with the lachrymal bone, which also covers in the cellular spaces here. (Plates 5, 69.)

The inferior border articulates with the orbital surface of the superior maxilla, and the posterior border does not concern us.

The os planum is usually intact, but dehiscences occur (Plates 48, 50), the importance of which will be considered with the anterior ethmoidal cells.

Before passing within the nasal cavity for the consideration of the inner wall of the lateral mass and the anterior ethmoidal cells, let us complete the internal orbital wall, as far as may concern us.

Lachrymal Bone (Ossa Unguis) (Plates 5, 9, 27).—Directly anterior to the os planum is the lachrymal bone with its two surfaces and four borders. The bone is thin and scale-like, with no cellular spaces.

The outer or orbital surface is divided unequally by a vertical ridge called the lachrymal crest, giving origin in part to the tensor tarsi muscle. The surface posterior to this crest is smooth and is in direct continuity with the surface of the os planum, the inferior lamina of the orbital portion of the frontal bone, and the orbital surface of the superior maxilla. The surface anterior to the crest is narrower but longer than the posterior, is concave throughout its vertical extent, and prolonged inferiorly in order to complete the inner and posterior bony canal for the nasal duct. The superior portion of this surface lodges the lachrymal sac.

The inner or nasal surface of the lachrymal bone is char-

acterized by a groove corresponding to the lachrymal crest. Running obliquely across the surface from before backward and downward is the inferior border of the uncinate process of the ethmoid bone. This border is in contact directly, or by means of small processes, and in the natural state the soft parts complete this continuity. (Plates 8, 10, 11, 12.) The upper surface of the nasal aspect of the lachrymal, as thus marked off by the uncinate process, goes to complete, externally, certain of the anterior ethmoidal cells, oftentimes the cellular space corresponding to the agger nasi (see inferior ethmoidal turbinate), and a portion of the upper and outer wall of the infundibulum. (Plates 5, 7, 9, 10.) This surface is marked irregularly by slightly elevated ridges corresponding to cellular laminæ of the ethmoid. (Plate 27.)

The somewhat triangular and smaller inferior portion of this nasal aspect forms a portion of the outer wall of the nasal fossa, situated on the same plane and articulating with the posterior border of the nasal process of the superior maxilla, and continues posteriorly with the upper portion of the uncinate process either directly by bone or in the recent state by mucous membrane. Directly external and anterior to this portion of the nasal surface is the nasal duct.

Inferiorly this surface is continued as a process to articulate with the lachrymal process of the inferior turbinate bone so as to complete internally the bony nasal canal. (Plates 22, 24.) Just before the lachrymal crest reaches the inferior border, it is continued as the hamular process, outward and forward along the edge of the orbital surface of the superior maxilla to the lachrymal tubercle of the same bone, so as to complete the bony ring of entrance to the nasal canal. This process may be a separate piece of bone.

The superior border is short, thickened at its anterior extremity, and articulates with the internal angular process of the frontal bone. It is in direct continuity with the external margin of the hiatus frontalis. (Plate 20.) The anterior border is the longest, articulates with the posterior border of the nasal process of the superior maxilla, and ter-

minates inferiorly with the prolongation which meets the lachrymal process of the inferior turbinate bone. The posterior surface articulates with the os planum provided the lachrymal bone is complete, otherwise it is a free ragged edge. It is not unusual to find the posterior portion of the lachrymal bone deficient (lachrymal dehiscence), in which case the continuity is restored by fibrous membrane. The inferior border, divided unequally by the lachrymal crest, articulates posteriorly with the orbital surface of the superior maxilla, anteriorly with the inferior turbinate as a rule.

In some instances where the lachrymal bone is small or deficient, compensatory laminæ from any neighboring bones may complete this internal bony wall of the orbital fossa. The relations about this bone are of much importance in the surgery of the anterior ethmoidal cells and frontal sinus.

Continuing the internal orbital wall forward (Plates 5, 9), it is seen to be completed by the nasal process of the superior maxilla. This process is a dense, rather vertically placed lamina of bone, projecting from the upper and front portion of the superior maxilla. Its external surface is smooth, slightly concave, gives origin to certain facial muscles, and is perforated by nutrient foramina. It continues anteriorly with the external surface of the nasal bone. Its internal surface (Plates 10, 11) forms part of the outer wall of the nasal fossa. A small upper portion is roughened and continues around to the thickened posterior border, articulates with the anterior extremity of the lateral mass of the ethmoid, thereby completing certain anterior ethmoidal cells. (Plates 20, 24.) Just below this small area is the superior turbinate crest for the anterior extremity of the inferior turbinate of the ethmoid (so-called "middle turbinate bone"), and also, in most cases, the anterior extremity of the inferior border of the uncinate process. (Plates 10, 11.) At the lower border of this nasal surface of the process under consideration is a second horizontal crest, for articulation with the inferior turbinate bone. Between these crests the surface is slightly concave and quadrangular, not so smooth as the

outer surface, covered in the recent state by mucous membrane, and forms a very firm boundary of the outer nasal wall. To a more or less degree this surface is overlapped by the inferior turbinated bone of the ethmoid.

The superior border of the nasal process is very short and thick, and deeply and finely denticulated for articulation with the frontal bone. This suture is at the anterior edge of the hiatus frontalis, extending laterally to be continued by the superior border of the lachrymal bone. In front, towards the median line, this suture is completed by the nasal bone (Plate 1), the upper border of which is equally thick as compared with that of the nasal process of the superior maxilla. Between the two internal angular processes of the frontal bone is the frontal notch, for the reception of the nasal processes and nasal bones. This region is just anterior to the margin of the hiatus frontalis of either side (Plate 15), and to the bony space between these openings into the frontal sinus, which is the lower, often much thickened, border of the interfrontal septum. (Plate 56.) According to the deviation of this septum, the size of the hiatus frontalis, the relative width of the nasal bone and nasal process, a part of the superior border of the nasal bone must be considered as bounding this hiatus. This partial bony ring bounding the anterior and lateral aspects of the hiatus is of much surgical importance in operations for curetting the cells about the ostium frontale and the complete removal of the nasal portion of the floor of the frontal sinus. (Plates 15, 16.) (The terms "hiatus frontalis" and "ostium frontale" must not be confused. The former refers to the opening in the frontal bone itself, and practically indicates the extent of the nasal portion of the floor of the frontal sinus after the ethmoid bone has been removed. The ostium frontale refers to the foramen of communication between the frontal sinus and nasal cavity when all the bones are *in situ*.)

To return to the nasal process of the superior maxilla. The posterior border, very thick, is marked by a groove which crosses diagonally from above downward and inward,

and lodges the lachrymal sac and nasal duct. The inner border of the groove articulates with the lachrymal bone, the outer border is the anterior boundary of the inner wall of the orbital fossa. The anterior border is comparatively thin, and articulates with the nasal bones. (Plates 5, 9.)

Nasal Bones.—The general curves of the external surface of the nasal process of the superior maxilla and of the anterior wall of the frontal sinus are continued on to the outer surface of the nasal bone, interrupted only by the sutures already mentioned. (Plate 9.) The thickness of the superior border has been noted. The inner surface, for the most part, belongs to the lateral wall of the nasal fossa (Plate 11), but a small median strip forms the anterior limit of the roof of the nasal fossa, and is directly continuous posteriorly with a portion of the roof formed by the thick inferior border of the frontal septum (Plate 56), which in turn passes on to the lamina cribrosa. At the internasal suture the inner surface of the bones is raised to form the nasal crest, which is the beginning of the inner wall of the nasal fossa. This crest articulates for the whole or part of its extent with the nasal process of the frontal bone (Plate 11), otherwise with a portion of the lamina perpendicularis of the ethmoid, and on either side is a groove for the nasal nerve in its course from the nasal slit in the lamina cribrosa. Continuing the median line posterior and inferior to the median septum and nasal spine of the frontal bone, we come to the lamina perpendicularis, which forms a large part of the inner wall of the nasal fossa. (Plates 2, 77.)

It is of practical importance to note at this point, although a matter of repetition, that anteriorly and internally the hiatus frontalis is surrounded by an incomplete ring of often very dense bone, which may narrow its lumen or extend across the anterior portions of the nasal floor of the sinus, thus obstructing the passage of instruments from below, and serving as a troublesome barrier in external operations aimed to enlarge the opening between the frontal sinus and nasal cavity.

Let us now consider the inner wall of the lateral mass. (Plates 2, 3, 4, 21, 29, 30, 69, 70, 78.)

This lamina of rough bone, thicker than the outer wall of the labyrinth (os planum), passes vertically downward from the lamina cribrosa for a variable distance, serving both as the inner boundary of the labyrinth and as the superior portion of the external wall of the nasal fossa. It terminates below in a free curled lamina of bone called the inferior turbinate body of the ethmoid bone, but more commonly spoken of as the middle turbinate bone.

The superior border of this wall arises from the whole length of the under surface of lamina cribrosa, just external to the outer line of foramina cribrosa (Plate 13), so that its inner surface is grooved by the olfactory nerves, which reach it immediately on emerging from the foramina. This border is nearly parallel with the lamina perpendicularis, but is slightly convex towards the median line, hence the narrowest part of the roof of the nasal fossa is near the centre of the lamina cribrosa, and becomes wider in front between the nasal processes of the superior maxilla, and behind near the anterior surface of the body of the sphenoid bone. This narrow portion of the roof will average one millimetre to five millimetres wide. The wider it is, just so much more room is gained by the surgeon.

Running parallel and external to the superior border of this boundary of the lateral mass is a narrow strip of the lamina cribrosa from two millimetres to five millimetres wide. This has a free, external, ragged border in the disarticulated bone, but in the natural state it articulates with the superior lamella of the orbital plate of the frontal bone and enters into the formation of a part of the roof of both the anterior and posterior ethmoidal cells. This is the outer rim of the lamina cribrosa, is devoid of foramina, and is frequently hidden by the orbital plate if the latter is markedly prominent towards the median line. (Plates 16, 17, 76.)

Posteriorly this superior border passes from the cribriform plate to the under surface of the ethmoidal spine of the

sphenoid bone, and, curving outward, it descends on the anterior surface of the body of the sphenoid. The anterior border of the inner wall of the labyrinth becomes the anterior border of the inferior ethmoidal turbinate, and will be described below. The inferior border hangs as a thickened free edge of this same turbinate. (Plates 2, 20, 58.) The inner surface is rough and marked superiorly by vertical grooves for the olfactory nerves.

The most striking landmark on this surface is a deep fissure, the inferior fissura ethmoidalis, which marks off the posterior half of the inferior ethmoidal turbinate. (Plates 2, 3, 8, 29.) It arises somewhat below the centre of this surface about fifteen millimetres to twenty millimetres from the anterior border, and runs obliquely downward and backward towards the spheno-palatine foramen. Below it bounds the upper border of a portion of the lower ethmoidal turbinate, and above it is the lower edge of the succeeding ethmoidal turbinate. There may be one, two, or three of these fissuræ ethmoidales, with a corresponding number of ethmoidal turbinate bodies. Above and behind these one to three oblique fissuræ ethmoidales is a nearly vertical depression between the posterior end of the inner surface of the lateral mass and the anterior surface of the body of the sphenoid, known as the recessus spheno-ethmoidalis, into which opens the ostium sphenoidale. (Plates 2, 8, 18.) Into the fissuræ ethmoidales open the posterior ethmoidal cells by means of comparatively large foramina known as ostia ethmoidalia. (Plates 4, 8, 34, 39, 51.)

The region above and posterior to the superior border of the inferior ethmoidal turbinate belongs to the domain of the posterior ethmoidal cells, and need not concern us further.

Inferior Ethmoidal Turbinate (*middle turbinate of nose*).—The lamina of bone forming the internal boundary of the labyrinth, as already noted, is divided sufficiently for descriptive purposes into two triangles by the incisura ethmoidalis inferior and a line projected forward to the antero-superior

angle at the nasal process of the superior maxilla. (Plates 2, 3, 29.) The surface of the superior of these triangles is interrupted by the remaining fissuræ ethmoidales, which indicate the number of ethmoidal turbinate bones. This triangle does not concern us.

The inferior triangle is the inferior ethmoidal turbinate bone, a thorough understanding of which is of importance in the treatment of anterior ethmoidal and frontal sinus disease. This lamina of bone hangs with a free border which projects into the nasal cavity (Plates 20, 57), and presents two surfaces, three borders, and three angles for consideration.

The inner surface faces the septum nasi, is flattened above but convex below, particularly in the antero-posterior direction, on account of the curling outward of the lower portion of the bone. (Plate 62.) It is roughened throughout its whole extent, and grooved near its inferior border for the branches of the spheno-palatine artery, which run forward and upward. The bone, as a whole, is rather spongy, but occasionally its surface is smooth. Corresponding to the length of the fissura ethmoidalis inferior, the surface here makes a right angle, or the bend may be even more acute, so that the upper portion of the inner surface no longer presents towards the septum nasi, but looks upward. (Plates 29, 30, 75.) This portion of the turbinate may be twelve millimetres to twenty millimetres long, and about ten millimetres wide, and its direction is of value in causing pus from the posterior ethmoid cells and sphenoidal sinus to flow backward towards the pharynx.

The outer surface of this ethmoidal turbinate is concave, but somewhat flattened towards the superior angle. This external concavity is called the sinus of the turbinate, and it is in very constant relation to the bulla ethmoidalis and processus uncinatus, as will be described later. (Plates 67, 69, 70.) This surface is often rougher than the internal aspect of the turbinate, and characterized by depressions or pockets even of considerable size. The openings of these depressions may become constricted, thus giving rise to cell-like forma-

tions resembling the ethmoidal cells. There may be a single large cell or more commonly several smaller cells, all of which open into the space below and external to the inferior ethmoidal turbinate, known as the middle meatus of the nose. (Plates 57, 58, 68.)

The superior border is the longest, and has a bony attachment throughout its whole extent. Starting from the spheno-palatine foramen, it passes upward and forward across the superior turbinated crest of the palate bone, thence obliquely along the cells of the labyrinth, to reach the lamina cribrosa in front, then it is carried forward close to the median line, often in contact with the lamina perpendicularis and thickened inferior border of the frontal septum, to terminate on the inner surface of the nasal process of the superior maxilla. (Plates 4, 8, 10, 11, 29, 30, 34, 45.)

The anterior and shortest border of the turbinate begins at this point, is carried downward for a variable distance on the nasal process of the maxilla, commonly in conjunction with the anterior extremity of the uncinate process. The lower half of the anterior border bends a little backward, and continues to the inferior angle as a free border.

The inferior border is free and connects the inferior and posterior angles. (Plates 2, 3, 29, 30.) It is much thickened, curled outward, spongy, and traversed by small canals for vessels.

The posterior angle is at the junction of the superior and inferior borders, and is just below the spheno-palatine foramen, and on nearly the same vertical plane as the posterior angle of the inferior turbinate bone.

The superior angle is somewhat obscurely placed near the roof of the nasal fossa, internal to the ostium frontale. The space just external to this angle is frequently somewhat enlarged by carrying the anterior border forward on to the nasal process of the superior maxilla and increasing the concavity of the turbinate, so as to assume considerable importance on account of the openings from the frontal sinus, the frontal bulla, and anterior ethmoidal cells. This forward

prolongation of the cavity under cover of the turbinate is called the agger nasi by H. Meyer, and is comparable with an extra turbinate, as observed in some of the lower mammalia. (Plates 8, 12, 25, 30, 40, 51, 52, 58, 59, 65.)

The anterior angle is often very prominent, projects freely into the nasal cavity, and is formed by the junction of the inferior and anterior borders. This projecting flap-like portion of the turbinate is known as the operculum (Schwalbe), and is commonly removed in attempts to reach the frontal sinus and anterior ethmoidal cells from within the nasal cavity. (Plates 29, 30.)

The general outline of the inferior ethmoidal turbinate is somewhat variable, yet it never loses its triangular shape. The free portion of the anterior border may be long or short, in which case the operculum is more or less prominent, and the angle formed by the anterior and inferior borders acute or obtuse. A long anterior border lowers this angle and renders access to the labyrinth more difficult. The general plane of the turbinate is a vertical one, but it may be deviated strongly to one side or the other, thus lying in contact with the septum nasi, on the one hand, or be crowded against the labyrinth, on the other hand. (Plates 57, 59, 61.) Its normal, external concavity may be greatly exaggerated, and thus impinge upon the labyrinth. The space between the anterior border of the turbinate and the nasal process of the superior maxilla will be accordingly narrow or wide, to the operator's advantage or hinderance.

Now and then one or more deep furrows traverse the inner surface more or less parallel to and near the lower border, so as to give one the impression of the presence of an extra turbinate when viewed from the anterior nares. The lower border may be much thickened, or greatly rolled up externally, to form a sort of gutter along the lower edge of the sinus of the turbinate. (Plates 59, 60, 62.) Deep notches not infrequently interrupt the general contour of the free margin. Very rarely is the internal surface of this turbinate concave.

The formation of cells in the inferior ethmoidal turbinate has been considered in connection with the external concave surface (sinus), appearing in grades from simple niches to well-formed cells, having distinct ostia, which open into the middle meatus. This is the smaller and unusual variety of well-marked cell. In about 200 observations, turbinate cells were present in 18 per cent. of the cases. One-third of these were of the variety arising from the turbinate sinus,, two-thirds were cells differing in character and mode of origin, as well as location of their ostia.

This latter variety is characterized by the presence of one large cell rather than several smaller ones, is located more commonly near the anterior border, which may be eight millimetres to twelve millimetres wide. (Plates 45, 58, 65, 68, 70, 71, 80.) The turbinate may consequently fill up the space between the septum nasi and bulla ethmoidalis, or grow at the expense of either of these structures. Of these larger cells, two-thirds open above the inferior ethmoidal turbinate into what is commonly called the superior meatus of the nose. To be exact, there is usually a single ostium, and that is located on the superior border of this turbinate at the anterior extremity of the fissura ethmoidalis inferior, occasionally in common with one or more of the posterior ethmoidal cells. It is important to note that the ostium is at the apex of the cell, most unfavorable for drainage, and would discharge into the superior meatus in two-thirds of the cases, in common with the posterior ethmoidal cells and the sphenoidal sinus.

The cell may occupy a part of the turbinate only; or occupy the greater portion of it, when it has received the name of concha bullosa. The extent of the cell can be determined during life by means of the probe.

The remaining ethmoidal turbinate bones are situated above and behind the region under consideration (Plates 29, 30), therefore they do not concern us.

So much for the lateral and anterior boundaries of the lateral mass, and we have now to consider the structures be-

tween these walls and their relation to the inferior surface (nasal portion) of the frontal sinus.

Processus Uncinatus.—The processus uncinatus (Plates 4, 5, 8, 9, 11, 22) is a portion of the ethmoid bone consisting of a narrow, flattened, and somewhat curved bony lamella, which presents two surfaces, two borders, and two extremities. Its anterior extremity is attached to the anterior portion of the lateral mass of the ethmoid, in close proximity to the upper part of the anterior border of the inferior ethmoidal turbinate bone. (Plate 18.) From this point the process takes a direction downward, backward, and a little outward in a plane external to the turbinate bone, but the inferior border of the process follows quite closely, in many instances, the contour of the free margin of the turbinate.

An understanding of the relations of this process and the septa connected with it, is of extreme importance, for these conditions determine in part the formation of the ducts and orifices pertaining to the frontal and maxillary sinuses, as well as many of the anterior ethmoidal cells. The plane of the bone is somewhat vertical, but its lower end is a little twisted, so that each surface faces in three directions. This tilting of the process, in conjunction with the bulla ethmoidalis, and their mucous membrane connections, to be described presently, is an important determining factor in directing the flow of pus from the frontal sinus and some of the anterior ethmoidal cells.

Internal Surface.—The internal or nasal surface of the uncinate process faces inward, and to a lesser degree forward and downward. Its anterior portion is united for a variable distance to the outer surface of the anterior end of the inferior ethmoidal turbinate, and in conjunction with this it is carried forward to articulate with the posterior border of the nasal process of the superior maxilla, and thence to the inner surface of this process. (Plates 8, 11.) According to the extent of union between these approximated surfaces of the processus uncinatus and turbinate will be determined one of the modes of approach to the floor of the frontal sinus.

With the exception of this small anterior portion, the rest of this surface is free, and forms part of the outer wall of the nasal fossa, just posterior to the nasal process of the superior maxilla, part of the lachrymal bone, and lachrymal process of the inferior turbinate. There may be a space here, however, but the continuity is restored by mucous membrane. This surface passes down external to the operculum of the turbinate with a varying distance between them. (Plate 65.)

External Surface.—The external or infundibular surface faces outward principally, and to a lesser degree upward and backward. Its anterior portion is beautifully exposed on removal of the lachrymal bone, and viewing the surface from the orbital fossa. (Plates 5, 7, 9.) At once thin, irregular laminæ of bone come to view, connected with this surface so as to form broken, cellular spaces, which, when articulating with the corresponding slightly raised ridges already described on the internal surface of the lachrymal bone (Plate 27), complete certain of the anterior ethmoidal cells. Hence, external to this portion of the external surface are ethmoidal cells and lachrymal bone. Very soon, however, this surface becomes the inner wall of the infundibulum, soon to be considered at length, into which this group of cells usually opens. For the rest of its extent this outer surface, in the bony state, is seen to cross the margin of the orbital surface of the superior maxilla without touching it (Plate 9), and then to face the antrum of Highmore. In the recent state, before the mucous membrane is disturbed, this surface forms the inner wall of the infundibulum, and is shut off from the inner wall of the antrum, except at its lowest portion, whence various processes radiate to be attached or not, as the case may be, to the periphery of the bony outlet of the antrum, thus partially completing the inner antral wall. Aside from these slender bony processes, the processus uncinatus projects sickle-like nearly across the hiatus maxillaris, and distally helps form part of the wall of the antrum. (Plates 4, 8, 9, 11.)

Inferior Border.—The inferior border is convex down-

ward and forward. It arises superiorly in contact with the middle turbinate and nasal process of the superior maxilla, but for the rest of its course it is somewhat variable. As a rule, in the bony state, it follows down the posterior part of the inner surface of this nasal process, touches the lachrymal bone, and is free to the posterior extremity of the process.

Common variations are the following:

(1) Processes connecting with the lachrymal bone. (Plate 11.)

(2) Direct contact with nearly the whole of the lower part of the lachrymal line. (Plate 22.)

(3) Contact with lachrymal process of the inferior turbinate bone. (Plates 22, 24.)

(4) Union with ethmoidal process of the inferior turbinate bone,—very common. (Plates 4, 9.)

On the contrary, in the natural state, this border is never free, but unites with the lower or deepest portion of the gutter of the infundibulum, and is continued inferiorly as part of the internal antral wall. The ostium maxillare will be considered with the infundibulum.

Superior Border.—The superior border of the uncinate process is free both in the bony and natural state. It forms a concavity roughly parallel with the prominence of the bulla ethmoidalis, and in the natural state the slit between these parts has received the name of hiatus semilunaris, and is the only entrance to the infundibulum from the nasal cavity. (Plates 8, 22, 24, 33, 38, 39.) The mode of connection of its upper portion with the bulla ethmoidalis is the determining factor as to the extent of the naso-frontal duct, the extent and form of the upper portion of the infundibulum, and other relations of much surgical importance. These will be considered in connection with the modes of entrance to the frontal sinus.

Posterior Extremity.—The posterior extremity of the uncinate process lies approximately in the centre of the hiatus maxillaris, in the partial closure of which it plays a small part (Plates 5, 9, 11); but occasionally it may nearly fill this bony

hiatus by means of a very thin expanded lamina, one side of which is covered by antral mucous membrane, the other by nasal mucous membrane.

Two processes are very constant from this extremity, the maxillary and turbinate. (Plates 5, 9, 11, 23, 24, 26.) These processes arise more commonly from the inferior portion of the extremity, the maxillary process, as though it was the end of the processus uncinatus, bent up and carried upward and outward to the edge of the orbital surface of the superior maxilla. This process may be multiple or its completion may be wanting, but its presence is always partially indicated. If complete, it forms the posterior border of the ostium maxillare, and under these circumstances the normal entrance to the maxillary sinus is entirely surrounded by bone (Plates 23, 26), otherwise this boundary must be completed by membrane. This reflected maxillary process terminates the lower extremity of the gutter or floor of the infundibulum.

The turbinate process passes down from the lower border of the uncinate process between layers of antro-nasal mucous membrane to meet the ethmoidal process of the inferior turbinate bone. (Plates 4, 9, 24.) This process, together with others which may radiate from this extremity, does not concern us.

Ethmoidal Cells.—The ethmoidal cells are bony cavities, located, for the most part, in the lateral masses of the ethmoid bone (Plates 17, 21, 77), many of which are completed by articulation with neighboring bones, as already mentioned. These cells communicate with the nasal cavity by means of ostia which are to be found in the fissuræ ethmoidales or their homologues (hiatus semilunaris and fissure between bulla ethmoidalis and upper border of the inferior ethmoidal turbinate). (Plates 29, 30, 38, 46.)

Theoretically, it is fair to assume that there is some regularity in the arrangement of the septa which go to form these cells, but it is often very difficult to follow out this plan in practice. Zuckerkandl has suggested the following

arrangement of bony septa, which is very satisfactory at least for descriptive purposes. The labyrinth is bounded laterally and above by bony walls, which have been described in sufficient detail. Now, running across between these lateral boundaries are septa obliquely placed, corresponding to the lines of origin of the various ethmoidal turbinate bodies,—viz., in the line of the fissuræ ethmoidales. Most of these laminæ join the os planum, the others the lamina cribrosa. These planes are intersected by septa placed vertically in a lateral direction, which divide the mass into cells of somewhat equal proportion. Such an ideal arrangement, of course, naturally never exists. Certain cells are uniform and larger than others. Certain cells exist in some cases, are absent in others, and the shape of corresponding cells is never the same. This irregularity is to be explained by the crowding of the septa in one direction or the other, the addition of new septa and the loss of others.

The embryology of the ethmoid bone would suggest that the cells first appear and grow by the development of pockets or diverticula from the cartilaginous nasal wall during the early years of infancy.

The ethmoidal cells of the adult are divided into two groups, anterior and posterior. The former include all cells opening under the inferior ethmoidal turbinate bone ("middle turbinate") into the hiatus semilunaris or the fissure above the bulla ethmoidalis. The latter group includes all cells having their ostia in the one to three fissuræ ethmoidales. Hence these cells open above the middle turbinate.

As a rule, the posterior cells are fewer yet larger than the anterior, and their ostia are much larger.

Although the posterior cells may be involved in acute processes as often as the anterior, spontaneous resolution is more apt to follow, according as the general nasal mucous membrane becomes normal, on account of the large size of the ostia. The smaller ostia of the anterior cells are more easily obstructed by polypi and hypertrophies, hence are

more frequently the site of chronic suppurative processes. We will dismiss the posterior cells without further consideration.

We have now to study the anterior ethmoidal cells and their relations.

Bulla Ethmoidalis.—The bulla ethmoidalis (Zuckerkandl) or promontorium (Zoja) is a very constant eminence, of considerable importance as a landmark, made by the prominence of the walls of one or, less frequently, several ethmoidal cells. (Plates of most sagittal and many coronal sections.) It is situated on the lower inner aspect of the lateral mass, under cover of, and partially concealed by, the middle turbinate bone, and is immediately above the posterior half of the processus unciformis, with which it helps form the hiatus semilunaris.

The bulla presents itself as a more or less prominent, smooth, and rounded eminence, which is open to considerable variation both as regards size and shape. It is best observed on removal of the middle turbinate bone. The prominent convex surface of the bulla looks inward, forward, and downward. (Plates 22, 34.) If this surface is followed backward, it is seen to be continuous with the horizontal portion of the posterior part of the middle turbinate, directly under the fissura ethmoidalis inferior. Following the surface downward and outward, we come to the under surface of the orbital wall of the superior maxilla, and pass to the maxillary sinus (Plate 21), but in the natural state our progress would be arrested by the membranous inner wall of this sinus, unless, perchance, we should be in the location of the ostium maxillare, when our progress into the sinus would not be interrupted. (Plates 61, 62, 69, 70.)

Passing forward and outward over the bulla, its convex anterior surface is limited by, and corresponds very accurately to, the anterior border of the lamina papyracea. (Plate 21.) If we follow the eminence of the bulla backward and a little upward, we are arrested by a fissure formed by the junction of this surface with the insertion of the middle turbinate.

(Plates 4, 10, 38, 40, 41.) Near the lower part of this fissure is an ostium leading to the sinus of the bulla. This ostium is elliptical, and rarely located low enough to drain the bulla without residuum. There are usually one or more additional ostia in this fissure, situated above the one to the bulla which lead to cells located nearer the floor of the frontal sinus. Instead of several ostia in this fissure, we may have one long elliptical ostium, extending quite to the lamina cribrosa, so as to measure ten millimetres to fifteen millimetres. (Plate 42.) At the bottom of this long opening can be seen septa giving rise to cells.

In most instances the prominence of the bulla is due to a single, rather large cell, which extends outward until arrested by the lamina papyracea. (Plates 62, 67.) It is not unusual to have two cells form the bulla, only one of which reaches to the orbital wall. (Plate 70.) These upper cells extend between the laminæ of the horizontal plate of the frontal bone, and may push forward into the posterior border and posterior angle of the frontal sinus. The frontal bulla (Plate 53), to be considered presently, may be formed thus.

As a rule, the antero-inferior convexity of the bulla ethmoidalis corresponds to the upper concavity of the uncinate process, and forms the superior boundary of the hiatus semilunaris and a considerable extent of that of the infundibulum.

To summarize the relation of the ethmoid bulla, together with the cell of which it is a part, we have,—

Anteriorly and inferiorly, the infundibulum and hiatus semilunaris, with the processus uncinatus.

Internally, inferior ethmoidal turbinate bone.

Superiorly, a group of anterior ethmoidal cells, extending forward and sometimes backward, otherwise posterior cells reach over the bulla.

Posteriorly, the horizontal portion of the middle turbinate shutting off the fissura ethmoidalis inferior, and posterior ethmoidal cells. (Plate 75.)

Externally, the lamina papyracea.

Variations in the Bulla Ethmoidalis.—The average bulla

is about ten millimetres long, and extends over the superior border of the processus uncinatus towards the median line about two to five millimetres. (Plate 67.) Its whole convexity is rather uniformly prominent. As extremes, the longest bulla observed measured twenty-six millimetres, and the widest, thirteen millimetres. The smallest bulla consisted of a nearly flat lamina of bone, the free edge of which served to separate the hiatus semilunaris from the ostium of the bulla. (Plates 4, 33.)

Occasionally the convexity is drawn out like a nipple, directed downward so as to project below and internal to the uncinate process. (Plates 42, 44, 46.) In a few cases the bulla may be in contact, particularly in the recent state, with the superior border of the uncinate process, and be a serious hinderance to instrumentation. (Plates 25, 31, 37, 41.) A wide bulla may crowd the turbinate against the septum nasi. (Plate 67.)

Orbital Dehiscences.—Defects in the orbital wall of the labyrinth, known as dehiscences, are very unusual, except in connection with the lachrymal bone. These need no mention. Two cases have been observed where the os planum was partly defective and the bony lamina replaced by membrane. In both instances, the sinus of the bulla communicated with the orbital fossa.

These cases are pictured in Plates 48, 49, 50, but their great rarity divests them of much practical importance, otherwise they would offer little resistance to the passage of pus, either from the orbital fossa to the nasal fossa or *vice versa*, or give rise to emphysema within the orbit.

Hiatus Semilunaris (Plates 4, 8, 10, 11, 12, also 30 to 47 inclusive).—The hiatus semilunaris is a half-moon-shaped opening, as its name suggests, which leads from the nasal cavity (middle meatus) into the infundibulum. (Plates 65, 67, 75.) The parts which bound this opening have been more or less fully considered.

In the bony state, as well as the recent, the superior border is formed by the convex surface of the bulla eth-

moidalis, the inferior border by the superior free margin of the processus uncinatus. (Plates 22, 38, 39.) Posteriorly there is no bony limit, so that this portion of the lumen is completed by mucous membrane passing between these two bony landmarks. (Plates 11, 12.)

The anterior limit of the hiatus semilunaris is variable. It is made by the presence of a bony lamina passing from the anterior portion of the superior border of the processus uncinatus to the bulla ethmoidalis, or its continuation upward. (Plates 4, 8, 31, 34, 41, 45, 49.) Very occasionally this septum is membranous. Another not unusual mode of closure of the anterior end of the hiatus is observed where the insertion of the superior border of the middle turbinate passes directly across from the upper end of the bulla ethmoidalis to the processus uncinatus, without the usual formation of a pocket or sinus under the anterior upper extremity of this turbinate. In other words, what we are to designate as turbinate fossa later is not always separated from the upper extremity of the infundibulum by a septum, but these two cavities become one. (Plates 30, 40.)

A third variety, somewhat less common than the first, is where no such lamina is present until the hiatus has extended nearly or quite to the roof of the nasal fossa, under cover of the middle turbinate bone, close to the ostium frontale. (Plates 11, 12, 33.)

Thus we have three types of closure of the anterior end of this hiatus, which are of great importance in determining the route to the frontal sinus.

(1) By means of a septum between uncinate process and ethmoid bulla.

(2) Septum absent, hiatus reaches practically to orbital roof.

(3) No septum, as in Plate 4, but the middle turbinate takes its place. Really no fossa turbinalis present.

Ordinarily, the long boundaries of the hiatus are nearly parallel, and from two to five millimetres apart; the length of the hiatus will average about fifteen millimetres, with ex-

tremes at ten millimetres and thirty millimetres. The hiatus semilunaris may be narrowed:

(1) By over prominence of the bulla ethmoidalis antero-inferiorly. (Plates 31, 42, 46.)

(2) By tilting the processus uncinatus in one of two directions,—viz., pushing the process as a whole, or either extremity, backward, or by rotating the upper border outward towards the bulla. (Plates 25, 67.)

(3) By the addition of the soft parts. (Plate 32.)

(4) By pathological processes,—hypertrophies and polypi. (Plates 37–51.)

(5) Its lumen may be obstructed by abnormal proximity of the inferior ethmoidal turbinate bone. (Plate 61.)

Infundibulum (all plates showing hiatus semilunaris, ethmoid bulla, and processus uncinatus).—The hiatus semilunaris is the ostium of the infundibulum, so that the latter is always as long, and in almost every instance is somewhat longer. The infundibulum is a sort of foyer between the nasal cavity, on the one hand, and certain ethmoidal cells, the maxillary sinus and the frontal sinus in half of the cases, on the other hand. Like the hiatus semilunaris, the infundibulum is always present.

A considerable extent of the infundibulum is limited by mucous membrane only, so that a study of the skeleton alone is insufficient to determine its limits and shape. In general, the infundibulum is like a long, curved canal, convex antero-inferiorly, shallow at its posterior extremity, deep and generally lost to view at its anterior termination. It is bounded above by the inferior surface of the bulla ethmoidalis throughout the greater part of its extent, except anteriorly, where the bulla is replaced by certain anterior ethmoidal cells, already described. (Plates 22, 41.)

External Surface of the Infundibulum.—Following this on the skeleton, we generally have, below, the maxillary process of the processus uncinatus, then a fontanelle looking into the antrum of Highmore, and as we ascend we cross the free edge of the orbital plate of the superior maxilla (often

separated into two laminæ for the formation of the maxillary cells), and then pass on to the inner surface of the lachrymal bone. (Plates 5, 8, 9, 23.) The under surface of the bulla and cells above it is usually extended forward to bound a part of the external surface of the infundibulum. In the recent state this surface is intact, except for the constant location of the ostium maxillare, just under the orbital roof of the antrum, and an occasional ostium from a cell in the lachrymal region. (Plates 33, 39, 40, 41.)

The *internal surface* of the infundibulum throughout its whole length is bounded by the external surface of the processus uncinatus, but its breadth is completed in part by the hiatus semilunaris, and frequently a fold of mucous membrane, which continues the concavity of the superior border of the uncinate process. (Plates 39, 40, 41, 65, 67, 70.)

When the soft parts are undisturbed, the internal and external surfaces meet below at an angle so as to form a sort of gutter, which follows the general contour of the infundibulum. The infundibulum, therefore, is comparable to a gutter, the depth of which will depend upon the width of the processus uncinatus, together with its increase by mucous membrane, and also upon the lateral tilting of this process. (Plates 59, 65, 70.)

At the lowest portion of this concave gutter, extending somewhat on its outer side, is the ostium maxillare, well guarded and hidden from view internally by the processus uncinatus. (Plates 23, 38, 39, 40, 41, 61, 67, 69, 70, 73, 75.) The importance of this topography, as regards the drainage of pus and the association of accessory sinus diseases, will be considered in Part II, hence the importance of this detail. The posterior extremity of the gutter ascends more or less after passing the ostium maxillare, and may disappear smoothly on to the lateral wall of the nasal fossa, or be interrupted by the fold of mucous membrane to which reference has been made.

The ostium maxillare, therefore, is situated in a depression at the lowest portion of the infundibulum. Its size and

shape vary within narrow limits. It is usually oval, three millimetres to five millimetres long, and about half as wide, and is placed transversely at the highest part of the antrum, close to the orbital wall. If the maxillary process of the uncinate is complete, its contour is bony (Plate 23), otherwise mucous membrane fills in the deficiency. In 250 cases the ostium maxillare was never found wanting.

Accessory ostia for the maxillary sinus (Plates 32, 34, 35, 36, 38, 40, 41), present in about 10 per cent. of cases, do not enter into the present anatomical consideration.

Allowing a slight digression from strict anatomical description, let it be mentioned here, for the sake of emphasis, that pus, travelling from the antrum, must first pass the ostium maxillare, where it reaches the lower portion of the infundibulum, thence, in order to reach the middle meatus, it must ascend over the free edge of the uncinate process. (Plates 65, 69, 71.) Furthermore, *that pus having once reached the infundibulum from other sources, such as the frontal sinus and certain of the anterior ethmoidal cells, must of necessity gravitate towards the ostium maxillare, and enter the antrum, provided this ostium is patent.* So much with the head in the erect position, but, in that the head is constantly changing its position, this antral drainage will be favored or hindered accordingly. Elsewhere the clinical evidence on this subject will be considered.

We have now to consider the upper end of the infundibulum, the cells related thereto, the mode of entrance to the frontal sinus, and the *rôle* played by these structures in the formation of the nasal portion of the floor of the sinus.

The upper extremity of the infundibulum becomes enlarged, and its contour will depend on the distribution of processes sent off from the upper broad extremity of the processus uncinatus. (Plates 5, 7, 9.) On three walls, subject to constant variation, are to be observed ostia of anterior ethmoidal cells. Posteriorly are the openings (one to three) leading to cells anterior to the group situated above the ethmoid bulla, which may extend to the posterior angle of the

frontal sinus. On the outer wall are the ostia, connected with the cellular spaces, completed when the lachrymal bone is *in situ*. There may be only one such ostium or as many as six in a vertical row, according to the number of cellular spaces.

Anteriorly there is a very constant ostium, which leads to a cell often of considerable size. It is the uppermost cell external to the uncinate process, which it follows anteriorly to the posterior border of the nasal process of the superior maxilla, and is completed externally by the lachrymal bone. This cell makes the prominence known as the agger nasi. Its roof is completed by the termination of the processus uncinatus, which arches over it from within outward. (Plates 5, 20, 24, 33, 35, 39, 51.)

The infundibulum may terminate above as follows:

(1) In 47 per cent. of the cases there is an ostium opening into a canal which leads to the frontal sinus. This canal is known as the naso-frontal duct.

(2) In 53 per cent. of the cases the infundibulum has no connection with the frontal sinus. In these cases the termination presents the following varieties:

(*a*) May end in a cell of considerable size, just internal to the upper portion of the lachrymal bone, and even as high as the internal angular process of the frontal bone. This cell often corresponds to the prominence of the agger nasi. Common. (Plates 5, 31, 52.)

(*b*) May end in a dilatation forming a cell in the posterior angle of the frontal sinus. Common. May terminate in the same way, except in a much more prominent cell, which has forced its way into this angle and posterior border of the sinus, forming a prominence known as the frontal bulla. A cell of sufficient prominence to be called a frontal bulla (Plates 37, 51, 55, 70, 76) is of fairly common occurrence. Of these frontal bullæ, one-third open into the infundibulum, the rest into the turbinate fossa, except an occasional one opening into the fissure between the ethmoid bulla and turbinate.

(*c*) Very rarely the infundibulum ends blindly without dilatation or ostia.

In 10 per cent. of all cases there is no septum between the uncinate process and ethmoid bulla (Plate 11) shutting off the infundibulum from the usual dilatation or fossa under the extreme upper and anterior portion of the middle turbinate bone. (Plates 31, 34, 38.) In these cases (Plates 11, 30, 35, 40) the contiguous surfaces of the uncinate process and turbinate are adherent throughout over the prominence known as the agger nasi. In these cases there is no diverticulum, directly under the turbinate, for the probe to enter, but it passes at once through the hiatus semilunaris into a dilatation, representing both the usual turbinate diverticulum or fossa, and the upper extremity of the infundibulum, as a single cavity. From this cavity are ostia leading in different directions, as already indicated.

Turbinate Fossa.—In the great majority of cases it is possible to follow up on the external surface of the inferior ethmoidal turbinate nearly to the lamina cribrosa, and yet not enter the infundibulum, which is separated by a lamina of thin bone, which passes back from the processus uncinatus to the upward continuation of the bulla ethmoidalis. If there is a naso-frontal canal present, it is completed by this lamina.

This space, bounded internally by the extreme upper end of this turbinate, has been called by the writer, for descriptive purposes solely, the turbinate fossa. (Plates 4, 8, 31, 32, 38, 45, 49, 58, 61, 65, 74, 77.)

Naso-Frontal Canal.—The naso-frontal canal is the upward prolongation of the infundibulum, and it is completed by the lamina of bone, as just mentioned. The length of the canal will depend upon the extension downward of this lamina, and will vary from two millimetres to fifteen millimetres. (Plates 11, 12, 38, 40, 41.) The regularity of its course is inconstant, on account of the canal being impinged upon by neighboring cell walls. There may be no true canal

whatever, and the passage to the frontal sinus may be through an irregular series of ethmoidal cells. (Plates 7, 9, 52.) The canal terminates finally in an opening called the ostium frontale, which is located in the nasal portion of the floor of the frontal sinus. (Plates 11, 12, 16, 35, 72, 76.) A passage corresponding to this canal may end blindly in the bulla frontalis, as mentioned above. *If this passage under consideration fails to open into the frontal sinus, it loses its identity as being a naso-frontal canal, consequently in 53 per cent. of these cases there is no naso-frontal canal.*

In this percentage of cases the frontal sinus opened directly into the turbinate fossa with little or no canal, entirely independent of the infundibulum or any of the cells emptying into it.

A naso-frontal canal existed in 47 per cent. of the cases.

Openings into the turbinate fossa:

(1) It may be blind in all directions and contain no ostia. (Plate 38.)

(2) Fifty-three per cent. of the frontal sinuses open into it. (Plates 4, 8, 31.)

(3) Two-thirds of the frontal bullæ. (Plate 51.)

(4) Most of the anterior cells on the floor of the sinus anterior to the ostium frontale, and often some of the small cells just posterior to this ostium, which fill up the posterior frontal angle and belong to the group above the bulla ethmoidalis. These cells also open into the infundibulum and the fissure above this bulla and below the turbinate. The bulla frontalis is nothing more nor less than a very prominent cell belonging to this group, which protrudes well into the frontal sinus. The cells which crowd into the posterior border of the sinus likewise belong to this group.

To recapitulate the Ethmoidal Cells, we have Two Main Groups.—(1) Posterior ethmoidal cells,—all cells formed wholly or in part by the ethmoid bone, having their ostia above the line of origin of the inferior ethmoidal turbinate bone. These have not been considered in the foregoing pages.

(2) Anterior ethmoidal cells,—also formed wholly or in

part by the ethmoid bone, with their ostia in two grooves corresponding to ethmoidal fissures opening below the inferior ethmoidal turbinate into the middle meatus,—viz.,

(*a*) Hiatus semilunaris,—the ostium of the infundibulum.

(*b*) The fissure just under the inferior ethmoidal turbinate, which is continuous above with the turbinate fossa in line with its ostia, if any happen to exist.

These anterior cells have been grouped as follows:

(*a*) The one or more cells represented by the ethmoid bulla, opening by the ostium of the bulla.

(*b*) The cells just above, which crowd into the posterior frontal angle, and are in the vicinity of the anterior ethmoidal canal, which runs transversely across their apices. These may empty into the infundibulum, the turbinate fossa, or in the fissure just above the ostium of the bulla.

(*c*) The group of cells opposite the lachrymal bone, extending around in front of the infundibulum to the nasal process of the superior maxilla, and superiorly often to the floor of the frontal sinus. Most of these cells open into the infundibulum. The cell corresponding to the agger nasi belongs to this group.

Floor of the Frontal Sinus (*Nasal Portion*) *and the Ostium Frontale.*—We are now able to understand in a few words what structures go to make the nasal portion of the inferior surface of the frontal sinus.

This area is bounded, strictly speaking, by the circumference of the hiatus frontalis, but for surgical purposes it is carried backward into the posterior angle among the ethmoidal cells. (Plates 15, 16.)

Looking into a sinus with a prominent superciliary ridge, the lower part of this anterior surface (to which the ridge belongs) passes backward to the anterior margin of the hiatus frontalis, where there is usually a thick ridge. This is the point of articulation with the nasal process of the superior maxilla. (Plates 11, 51, 56.)

Keeping to our strict anatomical lines, this somewhat horizontal surface is a portion of the anterior surface, ren-

dered thus on account of a prominent bulging forward (superciliary ridge). This peculiarity does not appear when the anterior wall is flattened. (Plates 24, 29, 49.)

Just posterior to this ridge we come to rounded eminences, which extend outward and backward, and are made by cells described as opposite the lachrymal bone, and extending towards the nasal process of the superior maxilla. (Plates 9, 57, 72, 74, 76, 77, 79.)

Posterior and internal to the apices of these cells, quite close to the frontal septum, is an opening called the ostium frontale. The ostium is generally well back towards the posterior angle. (Plates 11, 12, 16, 37, 42, 65, 72, 76.) Posterior to the ostium we come at once to the apices of the cells represented as filling the posterior angle, which often are of sufficient prominence to overhang and obscure the ostium frontale. The bulla frontalis (Plates 37, 51, 77), if present, appears at this angle often obscuring the ostium, and extending laterally along the posterior border for a variable distance.

Now and then diverticula are seen to extend down into the nasal process of the frontal bone (Plates 11, 26, 37), and less frequently backward into the crista galli. (Plates 10, 26.) Diverticula occasionally run down vertically into the infundibulum, independent of the naso-frontal canal.

The sagittal measurement of this surface is not often more than ten millimetres, but in all cases it can be increased surgically with but little element of danger, by curetting the cells in the posterior angle. Laterally this floor corresponds to the width of the hiatus frontalis. Surgically more space is easily gained internally by breaking through the upper end of the inferior ethmoidal turbinate towards the septum nasi, inferior to the lamina cribrosa. (Plates 20, 59, 65.)

Ostium Frontale.—Little remains to be said concerning this ostium. It may be oval, circular, or linear with its longest measurement from two millimetres to eight millimetres. It is usually oval and about three millimetres long.

The most common location is well towards the posterior

limit of the floor of the sinus, close to the frontal septum. Each sinus has its ostium. One exception has been noted. (Plates 55, 67, 68.) Its methods of opening into the nasal cavity have been considered.

Lining of the Frontal Sinus.—The mucous membrane which lines the frontal sinus does not differ in essential characteristics from that found in the other accessory nasal cavities. In general, it is somewhat thinner than that found in the antrum of Highmore, and more easily detached from the bony wall of the sinus.

In section, it presents the following layers: Facing the cavity of the sinus is a layer of ciliated columnar epithelium, between the cells of which are interspersed a variable number of goblet cells. The cilia produce a current towards the ostium frontale. Underneath the epithelium is a layer of loose connective-tissue cells, between the meshes of which are glands and round cells. This layer is capable of enormous increase in thickness, in consequence of inflammatory processes, by the addition of the serous element and leucocytes from the blood. The cavity of small sinuses may thereby be obliterated, and the consequent pressure gives rise to excruciating pain. The lining of the frontal sinus contains fewer glands than that of the antrum, and their distribution over the surface is unequal.

Underneath this loose layer we come to a rather dense basement layer, composed of compact fibrous connective-tissue cells. This is next to the bone and serves as a periosteum. It is easily detached except in the vicinity of the ostium frontale, where it is continuous, directly or indirectly, as the case may be, with the mucous membrane of the nasal cavity. Delicate vessels, passing between the membrane and the sinus wall, help retain these structures in approximation.

The blood-supply of the sinus is derived from branches of the spheno-palatine and anterior ethmoidal arteries, and to a slight degree from arteries of external origin, just mentioned, which pass through minute foramina in the sinus walls.

The nerve-supply is mainly through the nasal branch of the ophthalmic division of the trifacial nerve. (Inzani.)

A Few Anatomical Facts of Surgical Importance.—It will be obvious that in operating upon the floor of the sinus, in the radical operation for empyema of the frontal sinus or of the anterior ethmoidal cells, the curette should be directed downward, inward, or backward; that externally we should avoid entering the orbital fossa through the lachrymal bone or os planum; that the posterior surface of the sinus and the region of the lamina cribrosa should be carefully avoided on account of the liability of entering the cranial cavity. Anteriorly the curette can be used with impunity against the posterior border of the nasal process of the superior maxilla.

The posterior surface possesses a curve which is very constant for each case (Plate 51), and any sudden interruption in its contour towards the posterior angle is generally due to cellular laminæ, convex anteriorly, and it will be safe to puncture these downward and inward.

The question of probing the frontal sinus and its practicability will be considered in Part II. Suffice it to say here that it is a comparatively easy matter on the cadaver to pass a probe from the sinus into the nasal cavity. On the other hand, with the nasal fossæ divided by a median sagittal section and the septum removed, it is often easy to enter the sinus, sometimes impossible, and often doubtful as to where the probe has gone. Removal of the upper anterior portion of the turbinate is of great assistance. Results obtained by passage of the probe in the natural state, by the anterior nares, are rarely to be trusted with absolute certainty. Granting that the probe enters for a considerable distance, if we are fortunate enough to pass the many obstructions and avoid the numerous ostia in our way, even then we can never know whether the end of our instrument is only in a frontal bulla or a single compartment of the sinus. The direct course to the sinus is usually interrupted by prominences or septa, and the ostium frontale may not face properly for the reception of the probe or canula. Attempts to force the

probe up into the sinus generally result in injury to the parts.

The relation of the ostium maxillare to the infundibulum has been considered in sufficient detail. In cases possessing a naso-frontal canal, it is not unusual to be able to pass a *straight* probe from the frontal sinus to the antrum, the probe passing successively the ostium frontale, naso-frontal canal, infundibulum, and ostium maxillare. A slightly curved probe can be made to do this frequently.

Where the ostium frontale opens into the turbinate fossa (53 per cent. of the 250 cases examined) the uncinate process is the principal determining factor as to whether a slightly curved probe can be made to enter the antrum. This could be done in numerous instances, and the course of the probe would be as follows: Ostium frontale, turbinate fossa, hiatus semilunaris, infundibulum, and ostium maxillare. In these cases polypi and hypertrophies easily tend to direct exudate from the frontal sinus into the infundibulum, and thence into the antrum. At the same time, it is possible to conceive that such obstruction could prevent drainage into the antrum.

It will be observed that the ostia of the various groups of anterior ethmoidal cells are distributed along the route from the frontal sinus to the antrum, and in very intimate relation thereto. Both the clinical and anatomical evidence is such that the involvement of these cells, in suppurative processes, may be either of primary or secondary connection with similar processes in the frontal sinus.

These considerations will be more fully discussed in Part II.

PART II.

THE ETIOLOGY, PATHOLOGY, AND TREATMENT OF SUPPURATION IN THE FRONTAL SINUS, TOGETHER WITH THE NECESSARY CONSIDERATION OF DISEASE OF THE ANTERIOR ETHMOIDAL CELLS.

Historical.

Frontal sinus disease has been recognized for many years, but, until recent times, only certain manifestations, now known to accompany a comparatively small number of these affections, were looked for, and properly interpreted. These symptoms are now known to be late developments in the history of these cases and include the presence of a tumor or fistulæ in the vicinity of the frontal sinus or inner wall of the orbital fossa.

During the last century such cases had been diagnosed and operated upon by one of the so-called external operations.

In 1839, Dezeimeris published an exhaustive treatise, as far as concerned the knowledge of that time. In 1859, Bouyer published the results of his anatomical and pathological research, and more recently (1872) we have the results of Steiner's investigations concerning the anatomy and development of the frontal sinus.

The most exhaustive work, however, on the anatomy and pathology of the nasal cavity and its accessory sinuses has been carried out by Zuckerkandl. From a descriptive point of view this work has never been equalled, but numerous practical anatomical variations and particularly relations have been published by clinical observers.

One of the modern operators was Ogston (1884), and his operation is still followed by certain surgeons. In recent years, frontal surgery has been developed by Lichtwitz, Luc, Schaeffer, Winckler, Nebinger, Jansen, Kuhnt, and others, and pathological researches particularly by Weichselbaum and Fränkel.

Etiology.—It is often a difficult matter to trace the cause of suppuration in any given case, but, nevertheless, there are certain factors which predispose or give rise to this condition. In the first place, most sinus affections are consequent on *infection* from some source or other. We know that different pathogenic bacteria may give rise to inflammatory processes on mucous membranes, and we find also that the same bacteria may exist in sinuses without causing any symptoms or changes whatever. The mere invasion of the sinus by some bacteria is sufficient to give rise to inflammation; in other instances, other factors play a more or less important *rôle*. For example:

Trauma.—Fractures of the frontal bone, involving the sinus, are not uncommonly followed by suppuration within the sinus. Tissues are bruised and may necrose. There has been an escape of blood into the sinus which may clot and obstruct the ostium, or the fracture may be such as to interfere with its escape, and finally these changes furnish a good nidus for the growth of bacteria, already present within the sinus, or introduced at the time of injury. If there is neither infection nor obstruction, such an injury will give rise to no trouble. If the obstruction persists, a chronic discharging fistula will result.

Injury by bullets and various weapons may give a similar result. Trauma may follow the careless use of instruments in the anterior ethmoid cells near the ostium frontale, and cause an inflammatory process to extend to the sinus.

Foreign bodies in the sinus, such as parasites, have been reported as causing frontal empyema.

Mechanical obstruction, without infection, gives rise to the condition known as mucocele. This may persist for

years without much discomfort to the patient, but it may become infected at any moment with complete change of the clinical picture.

On the other hand, obstructions may be of inflammatory origin, as evidenced by the development of hypertrophies and polypi. Inflammatory processes accompanied by or resulting in obstruction become acute, and must soon terminate in one of several ways, to be considered later.

Most cases of frontal suppuration are not accompanied by complete stenosis of the ostium frontale, although the ostium may be somewhat narrowed, but owe their origin and chronicity to certain bacteriological invasions, which give rise to pathological changes in the lining walls of the sinus. When deeply seated nothing but radical methods can prevent a continuation of the suppuration. These cases are said to be of infective or inflammatory origin.

Inflammatory Cases.—Bacteriological investigations have thrown much light on the causation and frequency of sinus affections, as well as their relation to the various infectious diseases. Inflammation in the sinus may follow: (1) Extension from neighboring foci of inflammation, particularly the nasal cavity. (2) They may be primarily involved in a general systemic infection. In these cases, whatever germ is causing trouble elsewhere, may also be found in the sinus as demonstrated by Weichselbaum and E. Fränkel.

(1) *Extension of Inflammation.*—It is undoubtedly true that many cases of frontal inflammation owe their origin to the extension of a process primary in the nasal cavity. They may arise almost simultaneously or may follow the nasal disturbance a week or more later. A common history is to learn that the patient has just recovered from an acute coryza and now complains of frontal pain, etc., while the nasal examination is negative. Most of these cases recover spontaneously, but they are of common occurrence. Autopsies prove these statements, and Turcsa offers a clinical case in evidence, where the patient had a frontal fistula, in which he observed that there was an acute exacerbation of the symp-

toms with every attack of coryza. The position of the sinus as a whole, and the location of its ostium, expose it less to nasal extension than that of the other accessory cavities, and these conditions tend to favor an early resolution.

Nasal obstructions and inflammations in connection with hypertrophies render the sinus liable to invasion. These cases may be of acute origin, or may develop slowly without subjective symptoms, and be discovered only after *nasal* causes for suppuration have been eliminated.

Caries of the frontal or ethmoid bones may involve the sinus according to their proximity.

(2) *General Systemic Infection.*—That sinus affections accompany or follow acute infection or suppurative diseases with any degree of frequency is a comparatively recent discovery, but this conclusion is demonstrated by recent bacteriological and pathological examinations at autopsy. In a series of 146 autopsies by E. Fränkel, sixty-three cases gave evidence of an acute or subacute affection in one or more of the accessory nasal cavities. The frontal sinus, however, was much less frequently involved than the other sinuses, the antrum of Highmore predominating in by far the larger proportion. Weichselbaum was one of the earliest to demonstrate this association of sinus infection with acute disease. Recent investigations show that diphtheria is commonly associated with acute involvement of the sinuses, and that these cavities may contain the Klebs-Löffler bacillus after its disappearance from the nasal cavity and pharynx.

Children are more subject to acute suppuration than adults, the reason of which is readily explained by the frequency of the acute infectious diseases peculiar to childhood. An enumeration, simply, of these causes is sufficient,—diphtheria, scarlet fever, measles.

In the adult acute or chronic diseases of the sinuses have been traced to the following causes: Pneumonia, influenza, erysipelas, cerebro-spinal meningitis, peritonitis, typhoid fever, variola.

Tuberculosis.—No evidence has been obtained to show

that tubercular infection is ever primary in the frontal sinus, and there are but few recorded cases where it has extended to this sinus from neighboring foci.

Syphilis.—Syphilitic affections of the nasal cavity are common, and the amount of destruction often extensive. These processes often extend in any direction, irrespective of the tissue which they meet, and thus invade the sinuses, give rise to deep-seated pathological processes of the soft parts, as well as to caries and necrosis of the bony walls.

Many of these cases recover under the influence of antisyphilitic treatment, but others remain unbenefited. The reason of this is due to the depth of the destructive processes and the usual mixed infection rendered possible by the syphilitic process, to which must be added mechanical obstructions to the removal of the exudate. These cases have a syphilitic origin, but their continuation and obstinacy under rigorous antisyphilitic treatment are due to secondary complications.

The common pathogenic bacteria found in the frontal sinus are pneumococcus lanceolatus (Fränkel), staphylococcus pyogenes aureus, staphylococcus pyogenes albus, and streptococcus pyogenes. Other bacteria of rare occurrence are bacillus influenza, tubercle bacilli, typhoid bacillus, and bacterium coli commune.

New Growths.—Primary benignant or malignant tumors of the sinus are very rare, but extension of malignant disease into the sinus is not uncommon. That new growths of any sort may sooner or later give rise to frontal sinus inflammation is obvious. They tend to obliterate the cavity of the sinus, obstruct its ostium, and in time become infected, thus giving rise to inflammatory complications.

Frequency.—The frequency of frontal sinus suppuration is impossible to determine. Most acute cases pass unobserved, and resolve spontaneously. Mild chronic cases may fail to give rise to symptoms of sufficient annoyance to the patient to cause him to seek medical advice. Many cases are obscured by other causes of nasal suppuration.

E. Fränkel's figures are interesting as showing that mild

or even severe acute cases of accessory sinus disease are common complications in acute disease, but that the frontal sinus escapes far more frequently than the antrum or sphenoidal sinus. In a series of 146 autopsies, sixty-three had one or more sinuses affected, but only five were frontal, none of which were suspected during life. None of these frontal cases were isolated, but were associated with inflammation of some other sinus.

In fifty autopsies taken at random, Engelmann found three cases.

Pathological processes were discovered in the sinuses which served as a basis for the investigations described in Part I, but owing to the nature of the material (dissecting room) many changes could not be recognized, hence no reliable data could be obtained.

The frequency of frontal sinus fistulæ occurring in the eye clinics of Vienna has been figured as one in 9000 eye cases, in Berlin as one in 18,000.

Pathology.—The inflammatory pathological changes found in the frontal sinus are those peculiar to mucous membranes in general, but certain variations and complications may arise on account of the fixed walls and small ostium of the sinus. Inflammation of mucous membranes does not differ in essential characteristics from inflammation elsewhere. In addition to the ordinary products of exudation we may have mucus and columnar epithelium, often ciliated. Nevertheless, the nomenclature and classifications of inflammatory processes are very confusing and inconsistent. Different names are given to the same pathological process, depending upon the different appearances of the exudate and the nature of the infection, as well as whether the ostium is patent or not.

It is found that the same source of infection, under different circumstances, may cause but slight disturbance, or, under altered conditions, may give rise to the most destructive processes or to various grades of disturbance between these two extremes. The same organism may appear in

both cases even in pure culture. Mixed infection may complicate the process with consequent variations in different directions. The exudate in acute processes will vary according to the severity of the process and at different times in its course, but the changes in the membrane itself are such as to characterize the disturbance as acute or of short duration. The exudate in long-continued or chronic cases may offer nothing to distinguish it from the exudate of acute cases, yet the mucous membrane, meanwhile, has undergone alterations which are more or less permanent and mark a distinct line of difference.

The inflammation of the frontal sinus mucous membrane will be considered under the following groups:

(1) Acute inflammation, characterized particularly by serous infiltration (œdema). (*a*) Exudative,—serous, fibrinous, seropurulent, and purulent. (*b*) Diphtheritic.

(2) Chronic inflammation, characterized particularly by connective-tissue formation. An exudate is always present, which may be identical with that seen in acute processes; meanwhile certain more or less permanent changes are undergone by the mucous membrane which alter its general character: (*a*) Scar-tissue or fibrous-tissue formation. (*b*) Hypertrophies and polypi may develop. (*c*) Cysts may appear. (*d*) Osteomata may be formed.

(3) Tuberculosis.

(4) Syphilis.

(1) (*a*) *Exudative.*—Acute inflammatory processes are characterized by the pouring out of a varying amount of serum into the submucous connective-tissue layer (inflammatory œdema). In the early stages there is no exudate on the surface of the mucous membrane. In addition to the serum leucocytes infiltrate this tissue, which begins to swell rapidly and assume a reddish color, on account of the dilated capillaries. As yet the epithelial lining remains intact, and no exudate has reached its surface. The swollen mucous membrane obliterates the angles and borders of the sinus, and where the sinus is small and the œdema extensive, the

sinus cavity may be completely filled. This is the period of congestion, during which there is no discharge into the nasal cavity. Sooner or later some of the serum, together with some leucocytes, escapes through the epithelial layer into the sinus. The serum, leucocytes, a few epithelial cells which may be thrown off the surface, together with a certain number of bacteria, go to make up the serum type of exudation. There is always a certain admixture of mucus in all instances so long as any mucous membrane remains.

If the ostium frontale is obstructed by the œdematous swelling or from any other cause, the exudate cannot escape, but accumulates under pressure, with a corresponding amount of pain which persists until this tension is relieved. As the inflammation advances, capillary hæmorrhages frequently occur, the round-cell infiltration is more marked in the vicinity of the glands, and there may be a slight amount of epithelial exfoliation.

The character of the exudate may vary and become more tenacious and sticky rather than watery. This is due to the coagulation of fibrin derived from the blood, and we have the so-called fibrinous type of exudation, but the condition of the mucous membrane remains unaltered. The amount of œdema has now probably reached its maximum, more cells are poured out into the serous exudate, which becomes more turbid and may be called seropurulent.

By this time several changes may have taken place. Either the exudate has appeared in the nasal cavity through an ostium which was never obstructed or the ostium has become patent, whereby there has been much relief from the acuteness of the subjective symptoms, or, on the other hand, there is still obstruction and the symptoms have not abated.

In the first instance, simple, non-obstructive, the pathological changes may advance no further, the serous infiltration becomes absorbed or exuded, the round cells disappear, the exudate remains seropurulent for a short while, gradually decreases, and perfect resolution takes place. This is

the history of simple acute cases, where all the parts are restored to normal in the course of ten to fourteen days.

The acute process may be more intense as manifested by the exudate, which contains a larger proportion of leucocytes and is called purulent. The exudate is now made up of a large percentage of pus-cells, often many red blood-globules, bacteria, exfoliated cylindrical ciliated epithelium, with more or less serum and mucus, and is alkaline in reaction. Even now, if the pus can escape, resolution may be complete, and all the symptoms disappear, for the changes in the mucous membrane have not materially changed. There has probably been an increase of the round-cell infiltration, more superficial desquamation, and hæmorrhagic pigmentation, but these are not necessarily permanent changes. If resolution should fail, and the exudation persist with free exit, the pathological process may change its nature, may give rise to permanent alterations, and thus become *chronic*.

If the ostium still remains obstructed, our condition is that of an *abscess in a bony cavity*, and nature will endeavor to provide an avenue of escape for its contents, if not anticipated by surgical intervention. Meanwhile, increased tension aggravates the symptoms, the mucous membrane becomes more infiltrated, more hæmorrhagic, and the superficial desquamation more extensive. The round-cell infiltration reaches the deeper layers, and finally the periosteum, and then the bony wall itself. The pressure and infiltration give rise to necrosis of the soft parts, an ulceration forms, followed by caries in some portion of the sinus wall. The moment that pus escapes from the sinus there is relief from pain. Any wall of the sinus may thus become perforated, but the thin inferior wall is the commoner site, and the clinical picture will vary according to the exact point of perforation. If the point of perforation is well towards the front of this surface and near the inner angle of the orbit, as is usually the case, there will be an abscess form just under the skin, which is commonly punctured, or may be allowed to take its own course and rupture later. The swelling sub-

sides and a fistula remains, which may continue to discharge pus indefinitely. If the perforation is towards the posterior part of the inferior surface, the pus will enter the orbit, giving rise to a secondary orbital abscess.

Although there is no direct evidence, there would seem to the writer to be every reason for believing that perforation frequently takes place in the nasal portion of the floor of the sinus, perhaps oftener than through its orbital portion. The reasons for this supposition are both anatomical and clinical.

In the first place, the cell walls of the ethmoid bone which complete the closure of the hiatus frontalis are thinner than the orbital portion of the floor of the sinus, and, other things being equal, ought to yield to pressure first. Again, it is becoming more and more evident that empyema of the frontal sinus is very often, if not almost always, associated with suppuration in some of the anterior ethmoidal cells. Again, the history of many acute cases of frontal suppuration is that of a sudden gush of pus from the corresponding nostril followed by relief from pain and eventual recovery or persistent discharge into the nose. This discharge may have made its exit either through an ostium which has become patent again or through a perforation in the nasal portion of the sinus floor. No one can say definitely what has happened. The prognosis in cases of nasal perforation ought to be better than where an external fistula is formed, for the latter is frequently associated with nasal occlusion of the sinus, and can be relieved only by operation.

Perforation of the posterior wall is not common, and naturally is almost always fatal, in consequence of an acute meningitis or less frequently a frontal abscess.

Perforation of the anterior wall is most unusual, on account of its thickness. It happened in Warren's case, and gave rise to a pneumatocele. (Plate 85.)

As a rule, the interfrontal septum remains intact.

Resolution rarely follows these very intense acute inflammations. The destructive processes are often extensive,

and the delay has been so long that the lymph-channels and blood-vessels and glands cannot remove the dense infiltration of round cells and other products of exudation. There is a proliferation of connective-tissue cells rich in nuclei, the mucous membrane remains thickened, and the exudative process continues, and we have a beginning process, without a marked dividing line, which we call a *chronic inflammation.*

Hence, in the exudative type of acute inflammation we have a process characterized by serous and round-cell infiltration, accompanied by various forms of exudate, without marked destruction of the epithelial layer. It may be followed by resolution or become chronic.

(*b*) *Diphtheritic Inflammation.*—Another type of acute inflammation (misleading on account of its name, in that it has nothing to do with the infectious disease) is diphtheritic inflammation. It is characterized at the outset by a destructive process whereby an exudate forms on an ulcerated surface, which cannot be removed intact without tearing the mucous membrane itself. It is a necrosis of the mucous membrane surrounded by an extensive round-cell infiltration.

It may occur on any mucous membrane, but must be extremely rare in the frontal sinus.

(2) *Chronic Inflammation.*—There is no definite dividing line between acute and chronic inflammation; the latter is usually preceded by a longer or shorter period of the former and the transition from one to the other is gradual. *The characteristic feature of the chronic process is the formation of fibrous connective tissue, which is permanent.* The membrane itself may undergo further changes, characteristic only of the chronic process, but the exudate may correspond precisely with that of the acute process, with the difference that a purulent discharge is commoner in cases of long standing. As a further complication, an acute exacerbation may supervene at any time on an old process, whereby the appearance of both the membrane and the exudate may become greatly altered.

At the beginning of the chronic process the mucous membrane is still œdematous, but the round-cell infiltration predominates. The tissue is very vascular and succulent, and there is a great excess of nuclei. These proliferation cells become spindle-shaped and develop into fibrous connective-tissue cells, also known as scar-tissue.

In appearance the membrane is thickened, pale, and translucent, and its surface somewhat irregular in consequence of the contraction of the fibrous tissue at various points. The thickening of the membrane tends to obliterate the sharp angles and borders of the sinus, and reduce the size of its cavity. On section, the cellular infiltration is particularly emphasized in the vicinity of the glands and nearer the epithelial layer than the periosteum. The older the process, the deeper the infiltration, and the greater the loss of epithelium, which may be slight at first. Excoriations, therefore, are late developments as a rule. The exudation at this early stage is usually seropurulent, made somewhat tenacious by the addition of mucus. This condition may last for months with no discomfort other than the constant presence of an annoying discharge from the nasal cavity.

These are the mild chronic cases, and are often amenable to simple therapeutic measures, if the ostium frontale is sufficiently patent.

Sooner or later, in all chronic cases, certain secondary changes take place in the mucous membrane, consequent on the contraction of the fibrous tissue and deeper extension of the infiltration.

These changes (already mentioned) are: (*a*) Increase of fibrous tissue with general hypertrophy; (*b*) cyst formation; (*c*) polypi and local hypertrophies; (*d*) osteomata.

(*a*) The hypertrophy, due directly to increase of fibrous tissue, has been sufficiently considered, as well as its effects in multiplying the thickness of the mucous membrane. Its hinderance to the successful relief of empyema will be considered under therapeutics.

(*b*) Cysts are commonly seen in the antrum of High-

more, but are much less common in the frontal sinus, as a result of chronic inflammation. They owe their origin to an obstruction of the ducts of the glands of the mucous membrane from the pressure of round-cell infiltration, or the contraction of the scar-tissue, whereby the glandular secretion accumulates and forms a cyst. Microscopic cysts are probably present in most chronic cases, but it is unusual to find them much larger than a pea. They may occur on any of the sinus walls, and are invariably multiple.

The smaller cysts are lined with ciliated epithelium, but the larger ones are lined in part with squamous cells. The examination of the contents of cysts may reveal the presence of pus, epithelial cells, granules, cholesterin, fat, mucus, and albumen.

Another variety of cysts is formed by dilated lymph-channels. These are very unusual formations, and are apt to be solitary and of comparatively large size. They are filled with serum and lined with endothelium.

Instead of gland-dilatation with cyst-formation the contracting scar-tissue may obliterate the entire gland. This always takes place more or less extensively in prolonged, deep-seated processes.

(*c*) *Hypertrophies and Polypi.*—Small irregular prominences on the surface of a chronically inflamed mucous membrane are of common occurrence. They give a granular appearance to the surface, and are pale and translucent.

They are due to slight myxomatous growths, on the one hand, and made more prominent by depressions from fibrous contractions, on the other hand. The mucous membrane is usually intact over their surface, but here and there small excoriations may be evident. This irregularity of the surface favors the retention of exudation, and hinders the action of therapeutic agents.

Polypi differ from these myxomatous hypertrophies only in degree. They may be single or more commonly multiple, and fill up the greater part of the cavity of the sinus. Their bases may be broad, but in most instances they are

constricted. These polypi differ in no respect from polypi which may develop on any mucous membrane.

They are far less common than cysts in the frontal sinus, and they rarely develop to be of sufficient size even to fill the sinus. In structure, they consist of a wide-meshed reticulated framework, containing serum and myxomatous tissue and a few wide, thin-walled veins, all covered with ciliated columnar epithelium.

There is considerable discussion as to whether polypi are primary or secondary to inflammatory processes in the mucous membrane of the nares and accessory sinuses, but the evidence is decidedly in favor of the latter supposition, although in some instances polypi may be of primary origin.

(*d*) *Osteomata.*—As the inflammatory process reaches the deeper portions of the lining of the sinus the periosteum becomes infiltrated with serum and round cells. Resolution may follow if the process is arrested in time, otherwise the proliferation of cells and capillaries advances, new tissue is formed, and in due time inorganic salts are deposited, forming bone. Thus the general thickness of the sinus wall may be increased, but more commonly the new formation of bone appears as thin plates, free or attached to the walls, or as tubercles and spicules.

This bone-formation presupposes a deep-seated inflammatory process, amenable only to radical operative treatment.

At any time during the progress of chronic inflammation acute exacerbations may supervene, and this is commonly the case. The clinical symptoms are altered, the chronic pathological changes remain fixed, but the œdema and additional round-cell infiltration, which characterize acute processes, are added. The usual outcome is that the chronic process becomes deeper seated.

Chronic inflammatory processes, therefore, are manifested by a new formation of connective tissue, complicated by changes in the superficial or deeper layers of the lining membrane, and all of these changes may take place with a comparatively intact epithelial layer, or, in fewer instances,

superficial or deep ulcerations may exist. The depth of the process and the inaccessibility of the part to ordinary therapeutic measures is sufficient explanation of the chronicity of these cases.

(3) *Tuberculosis.*—The characteristic appearances of tuberculosis are evident here as elsewhere on mucous membranes. The process is one of ulceration with connective-tissue proliferation, and generally extends into the sinus as a part of a local process elsewhere. (Further detail is unnecessary.) Tubercle bacilli have been found at autopsy in apparently normal sinuses in patients who have died of tuberculosis.

(4) *Syphilis.*—The manifestations of syphilis are common in the nasal cavity, whence they may extend to the accessory sinuses. The process is characterized by ulceration, with the possible destruction of all tissues, followed by extensive scar-formations.

The process may be so deep-seated and complicated by mixed infection that it may fail to yield to ordinary antisyphilitic treatment. Involvement of the frontal sinus is commonly secondary to local syphilitic ulcerations.

New Growths.—In addition to the inflammatory processes in the frontal sinus, we have the consideration of new growths, which need but a passing mention.

Fibroma rare.

Cholesteatoma rare. First described by Virchow as a new growth. Cases reported also by Wotruba. Not to be confused with collections of epidermis, as observed in the mastoid antrum.

Malignant Tumors.—Sarcoma, carcinoma. These are the results of extension in most instances, and offer nothing particularly characteristic when they invade the sinus.

Symptoms.—All symptoms may be classified as *local* or *general.*

General symptoms are of secondary importance in sinus affections, except in certain acute cases, and in some of the complications arising therefrom; hence these general

symptoms will be considered under local symptoms, as called for.

Local symptoms may be subjective or objective.

Subjective Symptoms.—Pain.—Pain is very characteristic of acute cases, and is often a symptom during the course of a chronic case. In acute cases, there are several causes which give rise to pain. The early pathological changes are followed by œdema of the mucous membrane, which consequently thickens so as to fill up more or less of the sinus, and even obliterate its cavity, if small. This œdema presses the nerve-endings on account of the resistant bony walls. This swelling may also occlude the ostium frontale with consequent retention of exudate, which tends to accumulate under pressure, and give rise to excruciating pain and secondary reflex symptoms.

A common history of the pain in these acute cases is as follows: Several days to two weeks after the cessation of an acute coryza the patient complains of pain in one or both frontal areas, which gradually increases in severity. It is worse when the head is lowered or after coughing, sneezing, blowing the nose, and any sudden movement. It is a constant ache without remission, but with occasional darting pains. Its severity increases slowly, and varies according to the degree of tension of the exudate or the amount of œdema, and may decrease slowly, but more commonly relief comes rather suddenly. This is due to the returning patency of the ostium and discharge of the exudate. Up to this moment there has been no nasal discharge, when suddenly there is a mucopurulent or purulent or even bloody discharge from the corresponding nostril. The pain now decreases rapidly, and may cease to be a further element in the case, provided the outlet remains unobstructed. The sinus may rupture into the orbit, also, with relief. Internal medication with antineuralgics is of no avail in these cases. Photophobia and shedding of tears on the affected side not rarely accompany the pain of this stage.

On the other hand, many cases run a mild course throughout. In chronic cases, pain is more commonly a

symptom of secondary importance; when present, it is due to the same causes, and is suggestive either of a simple retention or of an acute exacerbation of the inflammatory process. Most chronic cases complain of no pain, but rather of an occasional dull ache. Pain is referable to the frontal area, but when intense, it may radiate in any direction and resemble a neuralgia or migraine. In severe cases, it may be impossible to differentiate the pain accompanying frontal ethmoidal or antral inflammation.

Pain is frequently of such a nature as to be described as a headache, and is often accompanied by dizziness, with flashes of light before the eyes on coughing.

Tenderness.—Tenderness is a symptom of great value. In acute cases, it varies more or less with the severity of the pain.

In chronic cases it may be sufficiently acute to attract the attention of the patient, but very frequently it is too slight to be of annoyance, and is discovered only by the examiner. In all instances it conforms in area very closely to the frontal region. It is most marked, however, at the inner angle of the orbit, on the orbital portion of the floor of the sinus. The tender spot is internal to the supraorbital notch, which is a help in differentiating neuralgia.

Tenderness should be examined for, either by means of graduated pressure or percussion.

Altered Sense of Smell.—Patients may complain of loss of the sense of smell. This cannot be traced directly to the frontal inflammation, but is probably consequent on troubles in the nasal cavity itself.

Constitutional Symptoms.—During the course of acute cases there is more or less febrile disturbance. We may have chills with considerable rise of temperature lasting until the sinus begins to discharge its contents. These febrile disturbances need no further consideration.

In certain instances, the annoyance and worry of long-continued suppuration give rise to a chain of nervous phenomena, which, in time, may result in lowering the general

condition of the patient. Most chronic cases, however, rarely complain of subjective symptoms.

Objective Symptoms.—(1) In nasal fossa. (2) Over frontal area and at internal orbital angle and in orbital fossa. (3) In cerebral fossa.

(1) *In Nasal Fossa.*—If the ostium frontale is occluded, as is common in acute cases, and an occasional complication of chronic cases, there may be no nasal symptoms whatever. In late stages of acute cases and in all chronic cases, there is to be observed one symptom which is the most important we possess as regards its diagnostic value. *This sign is the presence of pus in the nasal cavity, and is of conclusive evidence if its source can be traced to the frontal sinus.* Concerning the pus, there is nothing characteristic as regards its color, consistency, or odor. The amount of the discharge may suggest some accessory sinus affection and occasionally the degree of inflammation.

The patient complains of a more or less constant discharge of pus, sometimes very offensive, which appears at the anterior or posterior nares. It flows more constantly by day, and tends to accumulate at night while the patient is at rest, but in the morning there is an excess of crusts and pus, which necessitate cleansing the nose at once on rising. Most cases of frontal empyema have objective symptoms referable only to the nasal fossa.

The consideration of localizing the source of pus in the nasal fossa, the differentiation of sinus affections, the value to be attached to the presence of nasal polypi and hypertrophies, will be considered under diagnosis.

(2) Over frontal area and in orbital fossa.

Objective symptoms in this group are consequent on prolonged obstruction to the discharge of exudate from the sinus. They are manifested by (*a*) local signs of inflammation; (*b*) presence of a fistula; (*c*) presence of a tumor; (*d*) inflammation in the orbital fossa.

(*a*) In acute cases, where the obstruction persists, the tension increases and the pathological changes travel deeper.

Sooner or later the upper eyelid becomes œdematous and slightly reddened. This swelling and redness extend towards the median line and up onto the frontal area, and their extent is limited only by the severity of the process. Pain and tenderness increase proportionally.

If the ostium becomes pervious before these changes have advanced too far, then resolution may supervene without further change, and the parts be restored to normal. It is unusual to get marked external signs followed by resolution, for the pathological process goes on to further destruction, unless arrested by surgical intervention.

In time an abscess forms, which discharges pus freely, and the swelling subsides and the subjective symptoms decrease. These changes may occupy several days, and be accompanied by considerable constitutional disturbances.

An examination of this opening with the probe shows that it communicates with the frontal sinus, which commonly remains occluded towards the nasal fossa. There may be no further subjective symptoms so long as this fistula remains patent.

(*b*) *Fistulæ.*—The presence of a fistula presupposes the history just mentioned, and indicates, besides, that there has been a necrosis of the sinus wall. Its presence simplifies the diagnosis of a suspected frontal empyema.

Its location is comparatively constant at the upper internal angle of the orbit, internal and posterior to the supraorbital notch. It is rarely external to this notch. With very few exceptions the perforation is in the inferior wall of the sinus, but a notable exception is a case pictured by Warren (Plate 85), which was complicated by pneumatocele, where the thick anterior wall was necrosed. Perforations in the anterior wall are generally along the superciliary ridge.

Other sources give rise to fistulæ in this vicinity, such as orbital abscess, lachrymal cysts, gummata, etc. (to be considered under diagnosis), but an examination of the pus from frontal cases may reveal the presence of ciliated epithelium.

These fistulæ persist until nasal drainage is re-estab-

lished (but may close temporarily only), or until the sinus is obliterated by surgical intervention.

(*c*) *Tumor.*—There are several varieties of tumor which may be connected with the frontal sinus, and appear in this area: Abscess (has been considered), mucocele, pneumatocele, malignant tumor.

Mucocele is a rather rare affection. (Case IV, Plate 83.) It is a tumor of very slow formation, and consists in the gradual dilatation of the weaker parts of the sinus walls in cases where an occluded ostium frontale prevents the escape of mucus. The cases may last for years, while the tumor progresses slowly without subjective symptoms. The slow, steady pressure causes the thin inferior surface of the sinus to yield, and the consequence is a tumor at the inner angle of the orbit. Its growth may be so gradual as to fill up a large part of the orbital fossa without ocular disturbance, although the globe of the eye, meanwhile, has been pushed well towards the malar bone. It may also crowd portions of the ethmoid labyrinth towards the nasal septum.

It presents a smooth, rounded surface over which the skin is freely movable, and on the periphery the surface seems to be continuous with the surrounding bone. The tumor is resistant in places and gives rise to the characteristic "egg-shell crackle," as demonstrated in Case IV, but in places where the bony wall is very thin or deficient, it feels soft and fluctuating. These variations give an unevenness to the surface. The tumor as a whole is immovable, except that in certain instances its size may be somewhat temporarily reduced by pressure. If there is a rupture in the sac, the contents may be squeezed into the nasal cavity.

Patients suffering from mucocele may complain of tenderness and pain, which are usually accompanied by a change in the size of the tumor. In Case IV the tumor would occasionally decrease considerably and its surface become hard and rough, but at certain seasons it would increase in size and give rise to some pain and be tender on palpation. These collections of mucus may become infected, assume the char-

acter of pus with consequent chain of acute symptoms, and then follow the course of an acute abscess connected with the frontal sinus. Unless infection creeps in, these tumors continue for years without rupture; otherwise fistulæ result.

The usual symptoms of mucocele are of a mechanical nature and vary according to the size of the tumor. They may be manifested as dislocation of the globe of the eye; disturbance of the action of ocular muscles; pressure on the optic nerve and ophthalmic vessels.

Disordered function of the lachrymal apparatus. The dislocation of the globe takes place so slowly that the function of the eye remains normal for a long time. The eye is pushed into the corner of the orbit opposite that occupied by the mucocele. Hence it is dislocated outward and downward, commonly with more or less exophthalmos. The fatty tissue, external to the globe, gives way so that the sclerotic coat may be in close proximity to the malar bone. The eye appears smaller than the opposite one, because it is pushed outward under the lids, which meet at the external canthus.

The action of the ocular muscles remains normal for a long time and coördination may never fail. In advanced cases, on the other hand, their function may be interfered with so that double images are formed. Diplopia has never been present in Case IV, although the globe is in contact with the malar bone.

Pressure upon the optic nerve may give rise to choked disk or atrophy of the optic nerve. Amblyopia or amaurosis may be the consequence. These cases are exceptional, and the tumor must be very large and extend back to the region of the anterior or even posterior ethmoidal cells.

Mechanical disturbance with the lachrymal apparatus is common, as manifested by the overflow of tears down the cheek, which, in turn, may give rise to a troublesome eczema. (Case III.) The intimate relation of the lachrymal sac and nasal duct with the thin lachrymal bone, which continues downward from the inferior surface of the frontal sinus (Plate 20), readily explains the frequency of these symptoms. The

lachrymal bone is often pushed forward and outward, forming part of the thin wall of the tumor which presses the lachrymal sac between the tendo oculi and tensor tarsi muscle so as to occlude its lumen.

Pneumatocele is a condition of very unusual occurrence. Simple cases are manifested by the presence of air in the cellular connective tissue in the vicinity of the sinus (emphysema), or still less frequently by a well defined tumor containing air, for the most part. Such conditions presuppose a communication with the nasal cavity. Helly has collected a series of nine cases, while Warren's case of double frontal pneumatocele following perforation of the anterior sinus wall is unique.

The causes leading to this condition may be:

Congenital or acquired dehiscence of the sinus wall. May have to differentiate from orbital dehiscences. (Plates 48, 49, 50.)

Fracture in the frontal bone allowing air to be forced up from the nasal cavity under the skin (emphysema).

Inflammatory processes are the common cause of pneumatocele, consequent on necrosis and perforation of the sinus wall, the overlying skin, moreover, remaining intact. This is the usual cause of this rare complication. Such pneumatoceles are of short duration, and are soon followed either by resolution, or, more commonly, abscess-formation.

New Growths.—New growths of a benignant or malignant nature, primary in the frontal sinus, are also among its rare affections. Their presence need hardly be suspected on account of any nasal discharge, but should be considered as a possibility on the appearance of any external tumor. This sinus may be involved by a part of a malignant growth originating in the orbital or nasal fossa, as occurred in two cases subjected to extensive operations by Gussenbaur. Primary malignant tumors of the frontal sinus are never diagnosed early, and when discovered are usually beyond help.

The local and possible constitutional symptoms can be readily understood.

(*d*) *Inflammation in the Orbital Fossa.*—Under the consideration of local inflammation we have seen that mild symptoms and signs may subside with complete resolution, or may end in abscess-formation, and rupture with consequent fistula, but without further destructive process. On the other hand, these processes can be carried further, and the orbital fossa and its contents involved in the inflammatory process. These complications must not only tend to obscure the diagnosis, but also to add to the gravity of the situation.

The constitutional symptoms occasioned thereby are those consequent on any febrile disturbance, and need no further mention. The local symptoms are of importance. The earlier signs are due to œdema or exudation in the internal and superior muscles of the eye, whereby their action is impaired. The usual site of necrosis is in the inferior wall of the sinus, which is in close proximity to the levator palpebræ superioris, rectus superior, rectus internus, and obliquus superior muscles. Hence ptosis is an early sign, together with inflammatory œdema of the upper lid. The ocular paresis or paralysis gives rise to diplopia, consequent on more or less fixation of the affected globe.

As the pus infiltrates the orbit mechanical symptoms due to pressure arise, similar to those described above, but more rapid·in their progress, and resulting in greater functional disturbance, in that the parts have no time to become adapted to the altered conditions.

Another group of symptoms follows when the eyeball itself is involved giving rise to changes which may permanently impair the function of the eye.

Finally, inflammation may be set up in the lachrymal sac or nasal duct, manifested as a catarrhal process or abscess-formation, both of which may lead to occlusion of the lumen of the passage.

(3) Signs and Symptoms referable to the Cerebral Fossa.

One of the possibilities which may result from inflammation in the frontal sinus is perforation of the posterior

wall. This may take place during an active inflammation of the sinus with obstructed ostium frontale, or at the time of operation, or weeks and even months later, in consequence of a slowly advancing caries.

In addition to the already existing symptoms, whether they be acute or quiescent, there is a sudden rise of temperature, usually ushered in by a chill. There is frontal headache, unrelieved by medication, and more or less acute pain. The usual amount of exudate from the sinus, if previously discharging, becomes lessened. In a short time the ordinary symptoms of an acute meningitis develop, and the case will progress with the usual variations until the fatal termination.

Focal cerebral symptoms are not frequent, but somnolence and delirium are common features. In the later stages, gravitation will carry the pus backward over the vertex or along the base of the brain, with consequent convulsions or other focal lesions. Perforation of the posterior wall is usually a fatal complication. A series of twenty fatal cases have been collected. The cause of death in twelve cases was a suppurative meningitis; in five cases, abscess of the frontal lobe, and in three cases both abscess and meningitis were present. In three additional fatal cases death was consequent on a thrombo-phlebitis, the frontal sinus serving as the source of infection.

The site of perforation was commonly just to one side and in front of the crista galli, although caries may occur at any point in the posterior wall.

Diagnosis.—Some cases of frontal sinus suppuration may be diagnosed at sight without questioning the patient, other cases need weeks of careful examination and consideration, and, finally, in many instances, the precise location of the suppurating focus must be left problematical until determined by exploratory measures, which may be of value in treatment as well as diagnosis. Many of the procedures used for treatment as well as diagnosis will be more fully considered under subject of treatment.

Conclusions are drawn from the previous history of the patients and from present *subjective* and *objective symptoms.*

Previous History.—A common antecedent history for cases of acute disturbance in the frontal sinus is that of a coryza, and that the frontal pain commenced from one to two weeks after the nasal disturbance began to resolve. We may obtain the history of the trouble which is possibly still existing in the nose, such as polypi, ulcerations, etc.

The patient may have sustained some injury to the frontal bone which has given rise to a sinus complication.

It is of importance to ascertain whether the patient has recently undergone some acute infectious disease, especially of the type previously considered.

Having exhausted the possibilities connected with the previous history, our attention is to be directed to the present symptoms of the case, both subjective and objective. Objective symptoms are of much greater importance than subjective, and with the latter alone a diagnosis must be somewhat problematical. A suggestive previous history, together with existing subjective and objective symptoms, make it easy to diagnose suppuration in some one or more of the nasal accessory sinuses, but a certain differentiation may be most difficult without undertaking operative measures.

At first let us eliminate all lesions not connected with the nasal fossa or its accessory sinuses, which may enter into the question of differential diagnosis.

Elimination of Lesions Extranasal.—Supraorbital Neuralgia.—Pain is more or less characteristic and tenderness is at supraorbital notch instead of nearer the median line on the floor of the sinus. Absence of nasal or febrile symptoms. History of neuralgia elsewhere.

Migraine, Hemicrania.—Characteristic location and attacks of pain. Absence of all objective symptoms of disturbance in the frontal sinus.

Orbital Complications.—Suppurative diseases in the orbital fossa or its vicinity must be carefully considered in every

case of suspected sinus, which may be complicated by similar lesions in this fossa. However, the presence of co-existing nasal symptoms will decide the question. For example,—

Orbital abscess may be primary in the fossa or secondary to perforation of the sinus wall. There is nothing distinctive in the abscess itself or the mechanical and inflammatory consequences. Its location in the upper internal angle of the fossa is more suggestive of frontal sinus origin. Nasal symptoms may be absent, for an occluded ostium frontale is the probable cause of orbital perforation, but the previous history and tenderness over the sinus walls may be suggestive.

Ptosis following cranial lesions is never accompanied by œdema of the lid or inflammatory orbital processes.

Lachrymal Sac and Nasal Duct.—Suppuration in these structures should always lead us to suspect trouble in the anterior ethmoid cells, which in turn are very frequently involved simultaneously with the frontal sinus. Stenosis of the nasal duct with abscess-formation is still more suggestive. Look for nasal symptoms.

Tumors.—A gradually increasing tumor near the upper and inner angle of the orbital fossa, of long duration, without subjective symptoms, occasionally slightly tender, its surface rather hard, often with very slight bony irregularities, is probably a mucocele. This may become infected at any time, with the consequent addition of the symptoms and results of abscess-formation, of primary or secondary origin in the orbit.

Malignant tumors call for no particular consideration here.

Fistulæ.—A fistula may lead to the orbital fossa simply, or be connected with the frontal sinus or anterior ethmoidal cells. It presupposes, as a rule, the history of acute process located either in the orbital fossa or the accessory sinuses of the nose. The ordinary location of frontal fistulæ has been considered. The presence of tumor or fistula in connection with nasal symptoms, or a suggestive history, sim-

plifies the diagnosis to a large extent. So much for the elimination of lesions external to the nasal fossa or its sinuses.

Nasal Fossa.—The objective symptoms in the larger proportion of cases of frontal suppuration are limited to the nasal fossa. *The important cardinal symptom is the presence of pus.* Hence, we must consider the following possibilities as the source of the pus-formation:

(*a*) *Acute inflammation* in the nasal fossa.

(*b*) *Chronic inflammation* in the nasal fossa, complicated or not by hypertrophies or polypi.

(*c*) *Suppuration* in cells of the middle turbinate.

(*d*) *Inflammation* in one or more of the accessory sinuses. Having narrowed our source of pus to these sinuses, the next problem is to determine which sinus is involved, and also to consider the question of association of sinus inflammation.

(*a*) *Acute Inflammation.*—During acute nasal troubles, it is difficult to decide whether the frontal sinus is involved at the same time. Frontal pain and tenderness are common symptoms attending a "cold in the head," especially during convalescence, and we are now led to believe that acute inflammation of the sinus, of a mild type, is of common occurrence. Delayed frontal tenderness or pain should always arouse our suspicion of local trouble; the continuation of a unilateral nasal discharge should lead us to examine for some sinus affection, but during the acute period of the nasal inflammation, symptoms and signs referable to an acute sinus inflammation are very frequently masked.

(*b*) *Chronic Inflammation in the Nasal Fossa and its Complications.*—Very frequently, the first problem to be solved by the surgeon is, as to whether there is any or sufficient cause in the nasal cavity to account for the quantity of pus which may be present there. Most chronic nasal disturbances are attended by a varying amount of exudate which may differ in no respect from that of the sinuses. Hence, without further detail, it will be necessary to eliminate all nasal causes of suppuration. This may cause considerable delay on account of the presence of hypertrophies and polypi which *per se* are

commonly the cause of suppuration. In addition, they may act mechanically, obstruct the infundibulum and ostium frontale, and be the only hinderance to the recovery from a sinus inflammation, as well as obscuring its existence.

The preliminary treatment of disturbances in the nasal fossa, therefore, may result in simultaneous cure of the frontal suppuration. The persistence of pus accumulation in the middle meatus under the middle turbinate bone, after the removal of all obstructions, points to a source in the sinuses.

(c) *Cells in the Middle Turbinate.*—A middle turbinate bone, when viewed from the anterior nares, may be seen to be broader than usual. This may be due to a deep sinus turbinalis, whereby the normal concavity of the bone is deeper than normal, or the turbinate may have a double wall, giving rise to the formation of one large cell, or occasionally several cells. The ostium of this cell is almost always at its apex, so that drainage is hindered, and much pus may accumulate therein. Turbinate cells open more frequently into the fissura ethmoidalis inferior, but enough open into the middle meatus to be considered in this connection. (Part I.) Suppuration in these cells may give rise to a considerable amount of exudate.

A deep sinus turbinalis can be differentiated from a large cell by means of the probe with but little difficulty.

(d) *Inflammation in the Accessory Sinuses.*—We are now supposed to have eliminated all possible external lesions in the vicinity of the frontal sinus, and to have decided as to whether some lesion of nasal origin is adequate to account for all of the exudate found in the nasal fossa. If further sources are suspected, careful and repeated examinations must be made to determine the site where this pus appears first.

The turbinate bodies and the ethmoidal fissures, or their equivalents, with their respective ostia, are so situated that pus appearing here or there suggests that it must come from this or that sinus, or from a certain combination of sinuses. Provided the normal cellular partitions are intact, pus ap-

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pearing above the middle turbinate bone must be derived from either the sphenoidal sinus, the posterior ethmoidal cells, and two-thirds of the cases where cells appear in the middle turbinate bone. The posterior location of these ostia in the nasal fossa and the contour of the turbinate bone (Part I) are such that exudate from these sources will tend to gravitate towards the pharynx in a great measure, but, nevertheless, it may reach almost any part of the nasal fossa, depending the much-mooted question of the value of this procedure cern us except by way of elimination.

Pus appearing between the middle and inferior turbinate bones may emanate from the antrum of Highmore, the frontal sinus, the anterior ethmoidal cells, and from one-third of the middle turbinate bones, possessing cell-like cavities. The problem is to determine which sinus or what combination of sinuses may be involved; it is a difficult problem, and one that many times cannot be solved with any degree of certainty.

All reasonable measures suggested for the diagnosis of sinus affections, whether of much value or not (provided they are not harmful), should be resorted to, because some little point may influence us one way or another in drawing conclusions.

Percussion over the frontal sinus or antrum is of value in deciding the question of tenderness, but their cavities are too small for sound differences to be detected when full of fluid, as Zenker would have us believe.

Transillumination.—Nothing would be gained by discussing the much mooted question of the value of this procedure in diagnosis. Only the conclusions of the most experienced observers will be given.

Antrum of Highmore.—(1) Its use is often of value; (2) A negative result will not rule out disease of the antrum; (3) A positive result should make us suspicious, but is by no means conclusive evidence of a pathological condition; (4) Normal sinuses in the same subject may give rise to great inequality of the intensity of the light for various reasons.

Frontal Sinus.—Transillumination has been practised in these cases by placing the light either in the buccal cavity or externally under the supraorbital arch. While antrum illumination may be of assistance, its use in suspected frontal sinus cases is anything but satisfactory.

The great variation in the walls of frontal bones, and the unsatisfactory relation of the position of the light and the sinus for the transmission of rays, render frontal transillumination of but little avail in practice.

Auscultation, with the simultaneous insufflation of air, is a procedure which is unwise, on account of the spread of pathogenic bacteria into healthy sinuses, and is of no practical value.

Association of Sinus Affections.—Having exhausted all external methods for the differentiation of the sinuses under consideration, with the possible satisfaction of some evidence gained one way or another, we must resume the nasal examination. The nasal cavity has been cleared of obstructions (pathological), and our one cardinal symptom is the presence of pus in the middle meatus under cover of the middle turbinate bone. As already stated, this exudate may be derived from several sources, and before considering a few cardinal symptoms for each one, let us examine the clinical evidence concerning the association of sinus empyemata, as well as any anatomical reasons for this association.

Empyema of the Frontal Sinus combined with that of the Anterior Ethmoidal Cells.

Clinical Evidence.—Luc states that frontal empyema is usually associated with the same disease in the anterior ethmoidal cells. Jansen was early to suggest this combination, and reports that in seven frontal cases, all were thus complicated; that the infundibulum was obstructed by hypertrophies,—demonstrated by operation. As a result of autopsy, Zuckerkandl, with an enormous experience, never observed a case of suppuration in the frontal sinus uncom-

plicated by ethmoidal. E. Fränkel performed 146 autopsies, and did not find a single uncomplicated frontal empyema.

Cases III and V of this paper suffered from empyema of the anterior ethmoid cells in connection with frontal empyema, demonstrated by operation. Evidence obtained by autopsy and operation is indisputable.

There are, on the other hand, undoubtedly many cases of primary origin in the frontal sinus, notably those which can be traced directly to external trauma, but the question naturally arises as to whether in time these cases do not frequently give rise to associated trouble in the ethmoid cells. This will depend upon the anatomical relations of these cells and their ostia to the sinus, and the course of the exudate, and also to the secondary pathological changes acting mechanically or by extension.

Anatomical Evidence.—The intimate relation between the frontal sinus and some of the anterior ethmoid cells and the thinness of their walls has been considered in detail in Part I, hence it will suffice here to enumerate a few of the salient points:

(*a*) The nasal portion of the floor of the frontal sinus is made up mostly of anterior ethmoid cells, which also crowd into the posterior angle and posterior border of the sinus. Their walls are very thin and easily broken through with instruments.

(*b*) If a naso-frontal canal is present, it is more or less surrounded by these cells on three sides,—viz., externally the cells completed by the lachrymal bone, in front the cells on the floor of the sinus just anterior to the ostium frontale, and behind by the cells above the ethmoid bulla, which crowd towards the posterior angle of the sinus.

(*c*) The ostia of these various cells generally open into the upper portion of the infundibulum on different sides, in close proximity to that of the naso-frontal canal, or into the turbinate fossa. (Part I.) These ostia of the cells are distributed with no reference to the drainage of the cells, and may face in any direction. The whole space under considera-

tion is small and the ostia are fairly numerous, so that they are all in very close proximity. Their irregular distribution is such that, no matter what the position of the head, fluid or pus from the frontal sinus tends to flow into some of these cells, so that at least they may act as reservoirs. In time, the constant irritation of pus may give rise to the development of hypertrophies and polypi. These increase the liability of secondary involvement of the cells by adding an obstructive element to the discharge of pus from the frontal sinus.

(*d*) Trauma, consequent on attempts to probe the ostium frontale, may open the way for infection. There are many clinical cases reported where the writer states that only the frontal sinus was diseased, but unless carefully examined at the time of a very radical external operation or post-mortem, there is absolutely no known method of determining with certainty that some of these cells are not involved.

Hence the clinical evidence and anatomical structure would point very strongly to an involvement, sooner or later, of anterior ethmoidal cells in connection with empyema of the frontal sinus.

Empyema of the Frontal Sinus as a Cause of Empyema of the Antrum of Highmore.

The Antrum as a Reservoir.—On account of the much larger size of the antrum than the combined anterior ethmoidal cells, and also from the fact that the former is a single cavity, the latter a series of very small cavities, pus collections in the maxillary sinus are more extensive and more easily recognized. Although the antrum may not be the seat of an inflammatory process, if it serves as a reservoir for pus arising elsewhere, even then this pus collection will give rise to symptoms equally annoying, and which must be relieved.

Let us first examine the clinical evidence in regard to the association of antrum and frontal empyema, complicated or not, as may be the case, with ethmoid suppurations.

Clinical Evidence.—In seven cases of frontal empyema, Lichtwitz noted one antrum complication.

Bryan cites a case of antrum empyema secondary to that of the frontal sinus.

Macdonald says that all of his cases co-existed with suppuration in the antrum and anterior ethmoidal cells.

Ortega states that if both antrum and frontal empyemata are present, the frontal is the primary.

Alexander notes that where frontal empyema is accompanied by the presence of polypi in the vicinity of the infundibulum, there is usually pus in the antrum.

Jansen reports seven cases of frontal empyema, all co-existing with suppuration in the ethmoid cells, six of which had pus in the antrum. He is of the opinion that most frequently we have to do with a combined empyema, and that isolated cases of antrum are more commonly of alveolar origin. He cites one case of suppuration in the antrum which followed his radical operation (see *Treatment*) for frontal empyema, and attributes this consequence to the use of tampons for hæmorrhage. The writer is led to believe that the radical external operation, where a large opening is made through the floor of the sinus into the nasal fossa, of itself is liable to be followed by pus in the antrum, if not already a complication. This statement is based on a study of the regional anatomy, and operations on the cadaver; it will be considered more fully under treatment.

Cases III and V are examples of the association of the three sinuses under consideration.

It is a comparatively simple matter to decide whether the antrum is involved, and it should always be done before operating on the frontal sinus. The inner wall of the antrum should be punctured through the middle or preferably through the inferior meatus, and the antrum contents aspirated, if in sufficient quantity; otherwise the sinus may be irrigated with a small volume of sterile salt solution after the nasal fossa has been cleared of pus. Puncture may be avoided if it is possible to catheterize the sinus.

The existence of ethmoidal empyema alone can be determined only by first eliminating the frontal sinus and the antrum.

Another strong point, suggesting that antrum empyema is often secondary to one of the other sinuses, is the fact of the obstinacy and incurability of many such cases. This obstinacy of antrum cases led Fillebrown to conclude that several cases were prevented from recovering from their antrum troubles on account of empyema of the frontal sinus, which was evidently present in each instance.

Anatomical Evidence.—A detailed account of the anatomy of the structures which intervene between the ostium frontale and the ostium maxillare, together with variations, etc., from the normal, has been given in Part I, hence only certain obvious conclusions need be tabulated here.

(*a*) In looking at the external wall of the nasal fossa, with the middle turbinate bone removed as far as possible, and this surface held at right angles to the observer, the ostium maxillare is very rarely in the field of vision. Very frequently it can never be seen, no matter how the specimen is held. This is accounted for by the fact that this ostium is concealed by the uncinate process, lies near its lower border so that the whole width of the process obscures the ostium from view. The distance of the lower border of the ostium from the free edge of the process will vary, consequently, according to the width of process and its lateral angle of inclination. (Plates 38, 39, 40, 61, 67, 70.) The ostium, therefore, is situated at the lowest part of the infundibulum, and extends somewhat on to its external wall, and could not be better placed to drain the infundibulum, otherwise a blind pocket would exist here. Hence, if fluids once reach the infundibulum, they must gravitate towards the ostium maxillare and thence into the antrum, provided the ostium is patent. The infundibulum acts as a sort of gutter.

(*b*) In a little less than 50 per cent. of the cases there is a naso-frontal canal which opens into the infundibulum from the frontal sinus. If there are no mechanical obstructions,

fluid will gravitate in every instance from the frontal sinus to the antrum, with the head in the erect position.

Many times a straight probe can be made to follow this course, and almost always a more or less curved probe.

Pathological hypertrophies may fill the infundibulum and divert some of the fluid from this course.

(*c*) In a little more than 50 per cent. of the cases the frontal sinus opens into the highest point of the turbinate fossa by means of little or no canal. Fluid gravitates at once into the general nasal cavity, passing under the middle turbinate bone. Now, very frequently the septum which separates the turbinate fossa from the upper end of the infundibulum is very narrow (Plates 11, 22, 33, 37), so that fluid soon gets into this channel, and its further course continues as above. A wide septum may prevent fluid reaching the infundibulum and cause it to gravitate into the nasal fossa. (Plates 25, 31, 32.) Such will be the result with the head in the erect position, but, in that the head is constantly moving, pus may gravitate in any direction. Frequently a slightly curved probe can be passed through this route (turbinate fossa and infundibulum) into the antrum.

(*d*) Pus from the anterior ethmoid cells will follow the same laws and course, in that it drains into the infundibulum or turbinate fossa, or both.

(*e*) Pathological hypertrophies serve both to deflect pus into the infundibulum from the turbinate fossa, and also as a mechanical hinderance to its passage into the nasal fossa, thereby raising tension and forcing it into ethmoidal cells and antrum, especially if it leaves the frontal sinus under pressure.

The comparatively intimate relation of all these ostia favors the passage of pus from one to the other.

Now and then, in the recent state, the superior border of the processus uncinatus may be so close to the bulla ethmoidalis that the hiatus semilunaris is merely a small ostium and the infundibulum a closed canal, with the ostium maxillare an opening in its side.

The use of the probe and canula, and their practicability

and value as means of diagnosis, will be considered under treatment.

Prognosis.—Inferences as to the prognosis of suppurative diseases of the sinus frontalis will naturally be drawn from the foregoing pages. A certain prognosis can never be given, notably in chronic cases, many of which never cease discharging.

Although these cases are rarely fatal, and often only a source of annoyance to both the patient and his companions (nasal discharge with odor), a prognosis should always be guarded and given with some degree of caution, on account of the possibility of extension to the cranial fossa with its usually serious termination. The frontal sinus is occasionally the source of serious septicæmic or pyæmic infection.

Acute cases generally resolve spontaneously in from one to three weeks. There is always the tendency to recurrence with every attack of acute nasal disturbance, and finally the frontal inflammation may become chronic.

Fatal complications come during a primary acute attack or an acute exacerbation in a chronic case.

Chronic cases frequently never recover and are liable to acute exacerbations at any moment. Aside from a constant nasal discharge, they may cause no further trouble. The influence of combined sinus-disease, as well as other possibilities, influencing the course of sinus suppuration need no further consideration here.

The nature of the bacterial infection is of some importance. Streptococcus and staphylococcus infections are more serious than pneumococcus infection.

We do not know why some cases resolve quickly, and others remain chronic. The varying degree of the virulence of the infection, the amount and character of the exudate, the location and depth to which the bacteria have penetrated with varying pathological results, and individual disposition and idiosyncrasy, are all uncertain factors which must enter into the prognosis of these cases.

Treatment.—Acute Cases.—During the acute stage of

inflammation of the frontal sinus there are no direct local measures which will be of much benefit, and in many instances attempts at internal local treatment will do harm.

The ordinary analgesics for neuralgic pain will not relieve many cases, and in certain severe attacks opiates must be used. Occasionally the coal-tar products—phenacetin, acetanilide, etc.—may be of some benefit, and no harm will come from giving them a trial.

It is not a good plan to use nasal irrigations during any stage of acute inflammation. It is not desirable, also, to inflate the nasal cavity after the method of Politzer. These procedures may spread infection in various directions.

It is desirable to reduce the nasal congestion as much as possible, with the idea of relieving obstruction at the ostium frontale, which is probably œdematous, and not sufficiently open to allow the frontal sinus exudate to escape.

It is a good thing to apply cocaine to the vicinity of the infundibulum and turbinate fossa, either as a fine spray or on a pledget of cotton carefully adjusted. This may relieve the congestion sufficiently to allow the exudate to escape, and it will relieve the pain for a time. An oily spray with menthol is cooling to the patient, and tends to relieve congestion.

External applications of cold to the frontal area may be followed by good results.

It has been suggested that forcible inspirations, with the anterior nares closed, will produce a negative pressure in the nasal fossa, with the idea of thus aspirating the exudate from the sinus. This can never overcome marked stenosis of the ostium frontale, but may be of some value in certain instances.

Any treatment that will improve the condition of the general nasal cavity, when acutely inflamed, will probably help resolution in the frontal sinus.

Chronic Cases.—The treatment of any given case of chronic suppuration of the frontal sinus will depend upon the nature and complex of symptoms presented.

In general, treatment may be classified as follows:

(*A*) Intranasal treatment.

(1) By means of the natural canal between the sinus and the nasal cavity, using the probe and irrigation canula.

(2) By perforating the floor of the sinus.

(*B*) External operations.

(1) On the anterior sinus wall.

(2) On the inferior sinus wall.

(3) Complete removal of both of these walls.

(*C*) Both of these methods may be combined by entering the sinus externally and making a large opening into the nasal fossa.

(*A*) *Intranasal Methods of Treatment.*—(1) *Probing the Frontal Sinus; Use of the Irrigation Canula.*—These methods are of value in diagnosis as well as in treatment, and, first of all, it will be advisable to consider the evidence as to the possibility of probing the frontal sinus.

Jurasz was one of the first to attempt this mode of treatment, and in 1887 he published a series of twenty-one cases, including both normal and pathological sinuses. He claims to have succeeded as follows: Five times the probe entered the sinus easily. Six times the probe entered with difficulty. Ten times the probe failed to enter.

Schutter attempted to treat these cases by means of irrigation, and reports two successes.

Hartmann, Gruenwald, and Jansen make use of the probe and canula for diagnosis, but they consider this method of questionable value in treatment.

As to the possibility of probing the sinus, opinions are at great variance. We have, on the one hand, the results of clinical evidence, and, on the other hand, the results of study and experiments on the cadaver.

Various results obtained by different observers are as follows:

Hansberg says that on the cadaver he was able to probe half of the cases. He uses a probe one-half millimetre to one millimetre thick, bent at an angle of 125 degrees thirty milli-

metres from the end. He measures off five centimetres on this probe to correspond to the distance from the floor of the sinus to the lower part of the anterior nares.

Zuckerkandl observed that it was very difficult to pass a probe from the nose to the sinus on the cadaver, and this conclusion is the result of an enormous experience.

Réthi gives a report of twenty-six cases, stating that he could probe six of them.

Katzenstein says there are many hinderances to passing the probe.

Winckler says he could probe one-sixth of the male and one-quarter of the female cases.

Ziem says that probing and syringing the frontal sinus yield doubtful results.

Cholewa says that he can probe 60 per cent. of the cases with the Hansberg probe.

Hartmann thinks 50 per cent. of all cases can be probed, and adds that nasal irrigation will cure most of the cases if the ostium frontale is free.

Herzfeld is emphatic in declaring that we cannot often pass a probe to the sinus without injury to the anterior ethmoidal cells.

Alezais speaks of various obstructions which prevent passing a probe to the sinus.

Kuhnt and Schech say they have never succeeded in passing the probe to the sinus and been sure as to the exact location of the end of the instrument.

Engelmann says that he could probe half of the cases.

Killian was successful in only a small percentage of the cases.

Lichtwitz experimented with thirteen sinuses (cadaver), and failed to enter in only three instances. He uses a probe one and a half to two and a half millimetres thick, bent at a right angle ten centimetres from the end. He states that the probe should enter the nose for a distance of seven to eight centimetres in order to be certain that the sinus has been entered. He admits that occasionally we cannot avoid

entering some of the ostia belonging to anterior ethmoidal cells.

Of seven cases treated by irrigation, all were relieved of the subjective symptoms, but only one absolute cure as regards the nasal discharge. Only after the failure of nasal treatment would he resort to the external operations.

It will be observed, therefore, that results and opinions differ widely concerning the possibility and practicability of treatment of frontal empyema through the natural opening of the sinus. Some authorities believe that the sinus can never be probed with certainty, others declare that at least 60 per cent. of the cases are amenable to this mode of treatment. The probes devised and lauded by one operator are condemned by another; the solutions successful in one case fail in the next.

Anatomical Evidence.—The ability or inability to pass a probe into the frontal sinus will depend upon anatomical formations in the first instance, and, secondly, the result will vary with the presence or absence of pathological changes.

Two hundred and fifty sinuses and their approaches have been examined with reference to the conditions which favor or prevent the passage of the probe to the frontal sinus. In the first place it is absolutely necessary that the operator should be very familiar with the regional anatomy in order to get the best results.

Examinations have been carried out on the following plan:

(*a*) Probes of different lengths and angles were passed through the anterior nares towards the sinus, and their position noted later.

(*b*) Portions of the middle turbinate bone were removed later, if found to act as an obstruction.

(*c*) The relations and variations of the uncinate process and ethmoid bulla were noted wherever they interfered with the passage of the instrument.

(*d*) The various ostia into which the probe was liable to pass were noted.

(*e*) The size, location, and plane of the ostium was noted, together with variations in the size and shape of the surrounding ethmoidal cells.

(*f*) The thickness of the various portions of the floor of the sinus.

(*g*) The various methods of approach to the ostium frontale.

(*h*) The necessary measurements for the two arms of the probe.

In Part I the regional anatomy has been given with sufficient detail, and only general results will be briefly considered here.

It was found that the passage of the probe through the nares with the turbinate bone undisturbed was attended with many difficulties, and one could never be certain that the distal end was in the sinus. Although it seemed to be buried to a great depth, the end was frequently found only in a very prominent frontal bulla or a long cell running exteriorly along the posterior border of the sinus, or in only a single compartment of a nearly divided sinus. These points can never be determined on the living subject by nasal examination.

It was found that removal of the operculum of the middle turbinate made exploration easier, but the greatest gain was made when an incision with the scissors (Plates 29, 30) enabled one to remove more of the anterior turbinate with the snare. Still more space was gained by removing a little more of the upper wall of the turbinate, as shown in most of the sagittal sections. As shown in Plate 30, the posterior portion of the turbinate need not be disturbed, so that it is really unnecessary to remove much of the turbinate bone as a whole.

This procedure is of almost absolute necessity in treating these cases, in order to give the pus a free outlet of escape. The region of the infundibulum and turbinate fossa is frequently obstructed with polypi and hypertrophies, which may be the sole cause of the persistence of the suppuration.

This upper portion of the turbinate is removed most easily by means of punch forceps.

The ethmoid bulla is only exceptionally an obstacle after the turbinate has been properly excised. It is posterior and inferior to the field of operation. It may be a hinderance to the flow of pus, however, if it is sufficiently developed to close the hiatus semilunaris.

The uncinate process is an important landmark in probing the sinus. Where the ostium frontale opens into the nasal duct, which, in turn, must pass to the infundibulum, the end of the probe must pass over the upper border of the uncinate process to reach the infundibulum. Hence it is easy to see that the shape and position of the process are of great importance. It may prevent our entering the infundibulum.

Having entered the infundibulum, we must pass through a naso-frontal canal of varying length, according to the width of the septum referred to (Part II), as passing between the uncinate process and the infundibulum. This canal may be straight, curved regularly in any direction, or it may be very crooked, in consequence of anterior ethmoidal cells crowding the canal in one or the other direction.

Hence the canal may offer no obstruction, or may prevent the passage of the probe to the sinus, provided no injury is done. In probing the sinus it is advisable to bend the probe in different directions, until finally it may be possible to enter the sinus.

Thus far we have considered the conditions where the ostium opens into the infundibulum *via* a naso-frontal canal, and the probe must pass through the hiatus semilunaris. This group will include a little less than half of the cases, and are by far the most difficult to treat.

About 53 per cent. of all cases have no naso-frontal duct, and then the ostium frontale opens into the turbinate fossa (Part I) by means of little or no canal. These cases are much easier to probe, for the point of the probe passes up under the middle turbinate bone, far forward, as high as it is

possible to go, and the ostium is somewhere along the apex of the fossa. (See plates with probes, etc.)

During life it is usually impossible to differentiate these very different types of approach to the sinus, on account of the small size of the region under consideration and its inaccessibility. If the clinician succeeds in passing a probe into the sinus, it is probably a case of the second type, and the probe has not entered the infundibulum. The removal of the upper extreme portion of the turbinate is particularly efficacious in allowing these cases to drain. On the cadaver, more than half of these cases could be probed, but very frequently the angle and length of the probe had to be altered for different sinuses. Where a naso-frontal canal existed probing rarely succeeded.

A common barrier to the progress of the probe was the existence of ostia of ethmoid cells, which may be numerous in the vicinity of the ostium frontale. If such a cell is entered, further progress in that direction means injury. A frontal bulla may be entered in a similar way.

During life it is impossible to decide where the point of the probe may lie, and on the cadaver the uncertainty is nearly as great. The slight variations in distance, in any given case, from the anterior nares to the upper anterior ethmoidal cells, on the one hand, and the frontal sinus, on the other hand, are at least equally balanced by the individual variations. Hence no absolute measurements can be of much value, and will serve only as a general guide.

The probes devised by Hansberg and Lichtwitz are equally valuable.

Obstructions or hinderances to the passage of the probe may be summarized as (1) variations in the middle turbinate bone; (2) variations in the uncinate process; (3) large ethmoid bulla; (4) small or crooked naso-frontal canal; (5) protruding ethmoid cells; (6) ostia of ethmoid cells; (7) pathological hypertrophies.

If a probe can be passed, then we should attempt to irrigate the sinus with some very mild solution, such as a

normal salt solution or a 2-per-cent. boric acid solution. Strong astringents are harmful.

The question as to when nasal treatment is to be adopted, and the length of time it should be continued, is an important one. Some authorities declare that extensive suppurations in the frontal sinus never get well under this mode of treatment. If such be the case, then delayed external operation is a loss of time, and it should be resorted to early. But there is ample evidence to show that nasal treatment may give satisfactory results. If a complete cure does not follow, the subjective symptoms are often relieved, and the preliminary operations in the nose add to the success of the external operation.

The only complaint may be on account of the annoying discharge from the nose, and on this account it is better not to subject the patient at once to the risk and disfigurement of an external operation.

Every attempt to pass the canula will not be crowned with the same degree of success, and the element of chance is considerable. Accurate notes of the route, hinderances, and all peculiarities of each case should be kept, as well as the angle and curve of the probe. If the symptoms are not very troublesome, weeks or months may be given up to this treatment. If the symptoms indicate that the probe does not enter the sinus, after all possible obstructions have been removed, then it is a waste of time to delay the external operation.

(2) *Perforation of the Floor of the Sinus.*—This procedure was done first by Dieffenbach and later by Tillaux. In recent times it has been revived by Schaeffer and championed more or less by Winckler, but condemned strongly by most authorities.

As suggested by Schaeffer, the instrument is to perforate the floor of the sinus median to the middle turbinate bone.

Schaeffer publishes a series of twenty-five cases, of which

he says that eighteen were cured. Winckler reports fifteen cases, with six cures.

On the cadaver, Winckler experimented with sixty-six sinuses, and was successful in entering thirty-five sinuses. He failed in twenty-two instances, on account of the thickness of the bone on the floor of the sinus, which averaged from two to five millimetres near the median line. In sixteen cases the floor was thick near the median line, but thin externally. With one exception the instrument entered the sinus anterior to the ostium frontale.

Engelmann experimented with ninety-seven sinuses and could puncture only seven times, according to Schaeffer.

Lichtwitz, in similar experiments, succeeded in three out of twelve sinuses. In eleven cases of empyema he concluded that he entered the sinus three times, judging from the length of the probe. Great resistance caused him to desist in seven instances, and an alarming case of collapse led him to abandon the procedure.

Mermod reports a fatal case of meningitis where the instrument perforated the lamina cribrosa.

An examination of a large number of sinuses shows that it is possible to perforate the floor in the great majority of instances according to Schaeffer's method, when the parts are exposed on sagittal section, but in the natural state this is a most difficult, uncertain, and dangerous procedure.

In the first place, it is extremely unsurgical, for we are working in the dark and performing a dangerous operation. We are very liable to meet an impassable bony wall, or to perforate the lamina cribrosa. We are internal to most of the anterior ethmoidal cells which may be the seat of the greater part of the trouble. An ordinary perforation would not give satisfactory drainage, and the sinus itself is never open to direct treatment by this dangerous method.

From an anatomical point of view, it is much more rational to perforate the floor of the sinus just external to the middle turbinate going through the anterior ethmoid cells. There is more available space and the locality is a

little less dangerous. On account of the probable association of suppuration in the anterior ethmoidal cells with frontal sinus suppuration, it may be a good thing to perforate these cells. There is danger of entering the orbital fossa. Killian, Jurasc, and Hartmann rather favor this procedure.

Although less dangerous than the puncture internal to the middle turbinate, both of these methods are too dangerous, as well as offering but little hope of relieving the condition, to be of any permanent value.

They are not in conformity with surgical methods, and possess but little therapeutic value.

If the removal of nasal obstructions and attempts to relieve the conditions by irrigation *via* the natural opening fail, then we should consider the advisability of the external operations.

A few considerations in regard to the treatment of suppuration in the anterior ethmoidal cells.

Before discussing the various external operations for the treatment of frontal empyema, it will be necessary to consider very briefly the treatment of suppuration in the anterior ethmoidal cells. The reason for this is obvious when we consider the frequent associations of these processes.

Bearing in mind the anatomical relations, we recall that there are several groups of anterior ethmoidal cells, all of which are either under cover of the middle turbinate bone or are above and external to it. Hence, in order to accomplish much by way of nasal treatment, it will be necessary to remove a portion of its anterior extremity. After this preliminary step, we may possibly be able to see the bulla ethmoidalis, which represents the lowest of these cells and usually the largest. It is the most distant from the floor of the frontal sinus and probably less frequently affected than the other cells. Its protruding eminence can be removed by means of punch-forceps, the burr-drill, or the curette without much danger. With great care, it may be possible to reach

the cells just above the bulla. On account of hæmorrhage, it is usually necessary to employ several sittings in order to accomplish this object.

Most of the anterior ethmoidal cells are located in the upper portion of the ethmoid bone, filling in the floor of the frontal sinus and extending backward from its angle to reach other cells, called posterior ethmoidal, on account of the location of their ostia, and then they extend downward to meet the cell or cells which form the bulla ethmoidalis. These cells are comparatively small and numerous, and when once involved, suppuration is probably general throughout them all. They lie just internal to the inner wall of the orbital fossa, may extend up between the laminæ of the orbital portion of the frontal bone, and consequently are just inferior to the lamina cribrosa.

These cells are practically inaccessible to nasal treatment, on account of their location and the consequences which may follow operation, and, in connection with the frontal sinus, they are the cells most frequently involved. The parts are concealed by the first hæmorrhage, so that further operation would be unwise, hence many sittings are requisite. Distances cannot be judged carefully on account of monocular vision and the inaccessibility of the cells, so that the natural consequence is a perforation into the cranial or orbital fossa, even without the knowledge of the operator at the time.

Just behind and above the bulla ethmoidalis are certain large posterior ethmoidal cells, which can usually be treated with safety intranasally, but externally and above we run the same risk as in operating upon the anterior cells. However, the posterior cells do not concern us particularly.

Hence, intranasally, only a very small portion of the anterior ethmoidal cells are accessible to treatment within the bounds of safety, whereas the cells commonly associated with frontal sinus empyema are beyond the reach of intranasal surgery. Attempts to curette them by this route are too dangerous and are in every sense "unsurgical." All

that can be done safely is to remove the anterior extremity of the middle turbinate as high as possible, and curette the cells in or about the immediate vicinity of the bulla ethmoidalis.

The safest and most radical mode of treating the anterior ethmoid cells will be considered later.

Suppuration in Middle Turbinate Cells.—If such a condition is suspected, resection of the requisite inferior portion of the turbinate bone is all that is required. The lower portion of the cell is thus removed, and it can no longer retain pus. If necessary, its cavity can be curetted.

(*B*) External Operations on the Frontal Sinus.

Before resorting to external measures it must be carefully decided for each individual case whether such a step is necessary. Certain acute obstructive cases demand an external operation at once, in order to avoid possibly a fatal complication, but most cases are not urgent, and the advantages to be gained by nasal treatment more than outweigh the disadvantage occasionally consequent on delay.

Most patients will refuse the external operation, if proposed at once, particularly the extreme radical operation aimed at obliterating the sinuses. Most external operations result in considerable deformity, which is a considerable objection to the radical operation, wherever the empyema symptoms are not very annoying. All things considered, it is best to attempt to relieve the symptoms by intranasal treatment as described above, and if this fails, we can resort to more radical measures.

On the other hand, aside from certain acute complications, there are cases where it can be decided at once that it will be useless to expect to derive much benefit from intranasal treatment, cases where we can be certain at the outset that only radical measures will be of benefit. In general, cases complicated with external objective signs rarely recover without external interference. This is due not only to sinus complications beyond the reach of intranasal surgery, but also to the associated empyema of the anterior

ethmoidal cells, which can be safely and thoroughly curetted from in front, either through the orbital fossa or with better satisfaction, all things considered, through the floor or inferior wall of the sinus.

Under this group should be included all cases complicated by fistulæ, and most of the cases of mucocele, also most of the cases complicated by abscess-formation about the frontal sinus.

The indications for some external operation may be tabulated as follows:

(1) Where the intranasal treatment has failed to accomplish the desired end.

(2) To remove the element of danger, particularly in acute cases.

(3) To avoid drainage into the cerebral fossa in suspected perforation of the posterior wall of the sinus.

(4) To remove the mechanical symptoms consequent on the presence of a tumor from any cause.

(5) For profuse, persistent, often fetid, nasal discharge.

(6) To relieve pain in certain cases.

(7) Whenever there is an external fistula, which fails to close, after a reasonable length of time.

Having determined upon some external operation, there are numerous questions to be decided. We may enter the sinus from the anterior or inferior wall, or combine both of these routes. We have then to decide whether we will depend solely upon external drainage without disturbing the floor of the sinus, or whether we shall make an opening down into the nose and then close the wound of entrance, or, finally, whether both external and internal drainage shall be combined. Some surgeons are still more radical, and believe that the sinus must be obliterated. The question of the extent of curetting, also, is open to argument.

Let us examine these various procedures as carried out by operators who have had the most experience.

The earliest external operations were performed on

cases complicated by fistula, but these were not commonly followed by cure.

In 1838, Riberi enlarged the communication of the sinus with the nasal cavity.

Péan was early to advise thorough curetting of the mucous membrane.

The modern operations date from 1884, with the method advised and practised by Ogston. He made a vertical median incision, four centimetres long, starting from the root of the nose and passing upward. The skin and periosteum were reflected laterally and the frontal bone trephined in the median line, thus opening both sinuses simultaneously. A trocar was then passed into the nasal cavity in the vicinity of the ostium frontale and the opening enlarged. The mucous membrane was then curetted, swabbed with a zinc chloride solution, and a drainage-tube, the size of a "crow's quill," inserted, and the external wound closed. He reports two successful cases.

With this operation, serving as a general type, we have numerous modifications, but, nevertheless, many radical differences.

Schmidt makes an incision along the eyebrow from the angle of the orbit and reflects flaps up and down. He makes a small hole into the sinus with a chisel, examines with the probe, and then acts according to circumstances. He passes a trocar into the nasal fossa, uses the curette on all the sinus walls, and leaves a gauze tampon in the sinus.

Schech would make this same incision with the same general treatment, and he takes occasion to add that intranasal treatment offers but little encouragement.

Gruenwold follows this same incision, particularly for anterior ethmoidal suppuration, but for frontal sinus cases he makes a nearly vertical incision parallel with the corrugator supercilii muscle, starting below about midway between the median line and the supraorbital notch. He separates the skin and periosteum, chisels a small hole into the sinus, and injects sterile water in order to make sure that he has

entered the right sinus. The sinus should then be explored with the probe, the opening enlarged, the mucous membrane curetted, the nasal opening curetted, if necessary, and the sinus packed with gauze. He does not believe in closing the external wound. He reports that he gets very little scar.

Silcock and Dundas Grant advise the external operations, but do not curette the opening into the nasal fossa. They advise passing a small wire through the naso-frontal canal and over it a small rubber tube, if possible, to act as a drain.

We come now to the more radical operations. Nebinger advises removal of the whole anterior wall of the sinus. He incises from the naso-frontal suture of the affected side along the supraorbital arch beyond the supraorbital notch, exposes the bone at once, and reflects the periosteum above, chisels a small hole, examines the extent of the sinus with the probe, and acts accordingly.

If conditions call for the radical operation, he erects a vertical incision four to six centimetres long, just to one side of the median line, raises this triangular flap so as to expose the entire anterior wall of the sinus, which he removes as extensively as possible. He probes the ostium frontale and curettes the vertical portion of the sinus last, on account of hæmorrhage. He endeavors not to injure the interfrontal septum, but if it is perforated, he removes it in toto.

He curettes the opposite sinus from this same opening, if accessible, otherwise he extends the horizontal incision across to the opposite side. He approximates the vertical incision but drains at the inner end of the horizontal incision.

The essentials of this operation are (1) complete removal of anterior wall; (2) complete curetting of entire mucous membrane followed by immediate tampons; (3) enlarging the nasal opening, but depending mainly on external drainage.

Krecke and Fehleisen depend mainly upon external drainage.

Jansen's operation consists essentially in removing the inferior surface of the sinus and making a large opening into the nasal fossa. His idea is to obliterate the sinus by allowing the orbital fat to fill its cavity. He makes an incision along the supraorbital arch, and separates the orbital periosteum well back into the orbit. He then proceeds to remove the orbital and nasal portion of the floor, and, in cases where the sinus is large, he removes a strip of the lower border of the anterior surface from one-fourth to one-half centimetre wide. He curettes a large hole into the nasal fossa, thereby removing the anterior ethmoid cells in the vicinity of the floor of the sinus. He maintains that he can thus inspect the antrum and sphenoid sinus as well as the anterior and posterior ethmoidal cells.

The operation is liable to give rise to considerable disturbance in the orbital fossa, and frequently requires several months for healing. Where the sinus is small, good results are obtained, but if it be large, the progress is slow and the deformity may be considerable.

Kuhnt is even still more radical in that he removes both the anterior and inferior walls. For simple cases, determined by exploration with the probe, he removes the orbital portion of the floor near the internal angle, but if the sinus is large, he erects a vertical incision at the inner end of his horizontal one, turns up a flap of skin, and then removes, completely, the anterior and the inferior surfaces of the sinus. Then he bevels the sharp edges of the sinus walls, to make the cavity as flat as possible, curettes the remaining surface, and strives to obliterate the sinus by causing the flap of skin to become adherent to the posterior wall. He does not curette the anterior ethmoidal cells unless they are involved, but depends upon external drainage.

In these cases the resulting depression must be very marked. If the sinus is very large, it is impossible to make the skin-flap reach the entire posterior surface.

Killian makes the usual horizontal incision just above the supraorbital arch, which he continues in the middle line

down on to the nasal bones. He makes an exploratory opening into the sinus, passes a probe into the ostium frontale, which he leaves in position, then, by means of a chisel, he separates the nasal bone from the median line, and turns this bone-flap outward. He then removes all the structures between the probe and the external opening. The lower part of the incision is to be closed at once and a drainage-tube inserted into the nose.

The external wound is not to be allowed to close until the walls of the wound are practically healed and not liable to occlude the lumen between the nasal fossa and frontal sinus.

Luc reports a series of cases subjected to the external operation. His early cases did not do well, on account of failure to enlarge the opening into the nose. Later he combined this large opening with external drainage, but now he thinks it wise to close the external wound, and depends upon the nasal drainage alone. He thinks the chances are better if the sinus can be obliterated, but the disfiguration consequent therefrom is a matter to be considered in every case. Luc enters the sinus through a large opening in the anterior wall.

Czerny reports a case where he attempted to turn a bone-flap, but the consequent suppuration interfered with the success of the operation. A curved incision was made over the glabella, convex below and with the base of the flap towards the median line. There was a large opening made into the nasal fossa and the external wound closed. The case did badly on account of suppuration, the wound had to be reopened and the other sinus treated. This complication defeated the object of the operation.

Gussenbauer reports two cases of extensive malignant disease in the orbits and accessory sinuses, which he approached by a very extensive plastic bone operation which exposed these parts, including the frontal sinuses.

Consideration of External Operations.—As will be seen from the foregoing pages, there is considerable choice as to

the best method to pursue, but at the outset it must be said that each case will usually present features that call for special consideration. Hence there are no definite rules to be followed.

Our problem is to relieve suppuration existing in a bony cavity (with consequent rigid walls) lined with mucous membrane, which has probably undergone permanent pathological changes. The situation is rendered more complex on account of the exposed location of the sinus, with the objection to a large or hideous scar. The presence of a fistula or a tumor gives us more reason for operating externally, and the consequent scar will be less objectionable.

On the other hand, most cases of frontal empyema have no external objective signs, hence it should be our object to leave as little deformity as possible.

Without going into detail, it would seem that the best mode of getting rid of a frontal empyema would be to obliterate the cavity of the sinus. This can be done provided the sinus is small, and, at the same time, the anterior ethmoidal cells can be curetted. The resulting scar may be very slight, but, where the sinus is large, the deformity following the removal of the anterior or the anterior and inferior walls is too great to recommend this radical procedure in many cases. Besides, a cure cannot be warranted and the deformity will always persist.

Although there exists a very radical difference of opinion as to the advisability of making a large opening into the nasal fossa from the frontal sinus, general principles would seem to indicate that a large permanent opening was the only logical alternative. It has certainly been followed by the most favorable results.

A glance at the pathological changes consequent on chronic inflammatory processes in the frontal mucous membrane will make it evident that this membrane should be most thoroughly curetted.

(*C*) External Methods of Operation.

(1) *Obliteration of the Frontal Sinus.*—Certain operators strive for this result in every instance. If the sinus is small, it can be readily obliterated, but frequently the condition of the case will not be materially improved thereby, because a small sinus cannot be the source of an excessive exudate into the nasal fossa. Careful investigation will show that the ethmoidal cells are involved.

A few unusual cases of suppuration in the frontal sinus will be observed where there is no nasal discharge, but there is a persistent external fistula (Cases VII and IX). This condition means that the ostium frontale is occluded, and that the ethmoidal cells are probably not involved. The size of the sinus can be determined by means of the probe passed through the fistulous opening, and upon the size will depend the best method of procedure. If the sinus is small, for example, not extending laterally as far as the supraorbital notch, and measuring vertically not more than ten to fifteen millimetres on the anterior surface, it may be an easy matter to obliterate its cavity. In the great majority of cases the fistula leads through the inferior wall of the sinus (Cases IX and X) and will serve somewhat as a guide. A curved incision should be made, starting just above and external to the inner canthus, extending upward and outward along the supraorbital arch, just below the eyebrow, nearly to the supraorbital notch. By means of a periosteum elevator the inferior wall of the sinus should be exposed and all hæmorrhage stopped in order to have a dry field of operation. Then the sinus should be entered carefully through this inferior surface (orbital portion of floor of sinus) by means of chisel, burr-drill, and bone-forceps, as may be convenient, and then this whole surface of bone removed. The interior of the sinus is to be thoroughly curetted without communicating with the nasal cavity, which is already shut off by an occluded ostium frontale. The best result will be obtained by letting such a sinus gradually close by granulation.

These small sinuses offer the best chance for relief by this means.

Where the sinus is larger, the removal of the inferior surface is less effectual, so that some surgeons remove the anterior wall in addition. This has been followed by relief in a few instances where the ethmoidal cells were not involved, but the common subsequent history of these cases is the presence of a permanent or a recurring fistula. In every instance, a more or less depressed scar will follow, and this is an objection of considerable importance. Hence, the complete obliteration of a large sinus is a difficult matter, and both the success and failure of such an attempt are followed by objectionable deformity. Furthermore, the sinuses which are small enough for us to attempt to obliterate with reasonable hope of success and with only a slight scar are not the source of a large portion of the exudate appearing in the nasal cavity. Clinical and pathological evidence shows that the anterior ethmoidal cells are also involved in the majority of these obstinate cases, where treatment of the frontal sinus alone fails to relieve the condition. Operative measures, therefore, simply for the obliteration of the sinus, without involving the nasal portion of the floor of the sinus or entering the nasal cavity, are of value only in a limited number of cases. In many instances, however, where the nasal portion of the floor of the sinus and the anterior ethmoid cells are curetted away through an opening in the orbital portion of the floor of the sinus, it is possible and probably desirable to let the soft tissues of the orbit crowd into the sinus and thus fill up and destroy the cavity. Free nasal drainage, nevertheless, is the secret of success in these cases.

(2) *Complete Removal of the Nasal Portion of the Floor of the Sinus.*—In considering the question of treatment of chronic suppuration in the frontal sinus, we must strive to understand why such suppuration is so persistent. In the first place we have to deal with a bony cavity, with consequent rigid walls, hence this space must remain as a cavity, unless subjected to the treatment just considered, which is

practicable in occasional cases. The outlet of this cavity is situated at its lowest part, but is of comparatively small size. The pathological changes which accompany chronic inflammation are such as to diminish the size of the cavity by filling it with hypertrophied and polypoid tissue. These changes decrease the size of the lumen of exit. Thus the retention of pus is favored and the changes in the mucous membrane are such that the sinus cannot be properly irrigated. Furthermore, as so often mentioned in these pages, the association of the frontal sinus and anterior ethmoidal cells is such that in the majority of cases it is useless to treat the sinus without destroying the complicated labyrinth of ethmoid cells directly under the nasal portion of the floor of the sinus. These bony cells give rise to and also retain the products of exudation, and thus tend to prevent recovery. They cannot be reached and treated with safety through the nasal fossa, but must be destroyed by means of an external operation.

The essential features in the treatment of these cases consist in the removal of the whole of the nasal portion of the floor of the frontal sinus, destroying the partitions in the sinus, the complete destruction of the anterior ethmoidal cells, and careful curetting of the whole region. Thus the cavity of the sinus may become lined with smooth walls and connected with the nasal fossa by the largest possible opening, and, moreover, there will be no ethmoidal cells to collect exudate or interfere later with irrigation of the frontal sinus from the nose. The mode of entering the sinus from without is a matter of cosmetic result and facility in performing the above rather than an essential in accomplishing the desired result.

Entering the Frontal Sinus through the Anterior Surface. —The favorite route of entrance with most surgeons is through the anterior surface, but if the resulting bony defect is large, the amount of deformity is considerable, even though the wound is closed at once. A small opening in the bone may be made which will be sufficient in some cases and

give good cosmetic results, but, as a rule, a careful and thorough operation cannot be done unless the cavity of the sinus is well exposed.

In order to avoid the usual depression over the sinus the following method of procedure is suggested as practised on the cadaver and carried out in Case IV. As a preliminary step the posterior nares should be tamponed, and thus there will be no annoyance whatever from blood entering the pharynx or larynx.

A curved incision, commencing over the upper portion of the nasal bone near the naso-frontal suture (Plate 81), is carried upward parallel with the folds of the skin made by the corrugator supercilii muscle for about fifteen millimetres, gradually curving outward over the glabella, and following the horizontal folds of the skin. The upper part of the incision is just above the eyebrow, and is carried boldly down to the bone without elevating the periosteum. By means of a burr-drill, or small trephine, an opening three to five millimetres in diameter is made through the anterior wall in the line of incision just above the supraorbital arch at the inner angle of the orbit. On the skull this point will be seen to be on the anterior wall of the sinus, just below the inner extremity of the superciliary ridge (Plates 1, 81). If any sinus is present in the vertical portion of the frontal bone, it will be situated at that point, otherwise the presence of diploe will be an indication of its absence. If no sinus is detected, the inference will be that the ethmoid cells are the source of the exudate, which can be treated as described below.

Having entered the sinus by this small opening, a careful exploration should be made with the probe to determine its extent in all directions, and, if possible, to decide as to the changes in the mucous membrane. If the sinus is very small, the opening may be enlarged a little, the mucous membrane curetted, and the nasal portion of the floor of the sinus removed in the manner to be considered. Where the sinus extends to the supraorbital notch or beyond, as is usually

the case, more room must be had for inspection and operation. For this purpose the original incision is continued horizontally in the folds of the skin and then carried downward to the supraorbital notch (Plate 81), so that the extremities of the incision are more or less concealed by the corrugator folds and the eyebrow. Meanwhile, the periosteum must not be disturbed.

Starting from the small exploratory opening in the bone, a bone-flap is to be chiselled corresponding to the line of incision, with the supraorbital arch serving as a base (Plate 82). Towards the median line the bone is to be chiselled as far as the naso-frontal suture, and then directly downward and backward towards the orbital plate of the frontal bone. The external extremity passes down across the arch to meet this same plate. Now it will be very easy to pry the bone-flap forward so that it will fracture along the thin orbital surface or floor of the sinus close to the arch. If done carefully, the entire piece of bone will be adherent to the periosteum. An extensive view of the sinus is obtained at once, whereby its whole cavity can be inspected and treated. After completion of the operation on the floor of the sinus, the bone-flap is to be replaced and the wound closed with interrupted or buried sutures. So much in regard to entering the sinus through the anterior wall. The great advantages of this route are that the whole sinus may be open to perfect inspection, and a large opening made into the nasal fossa without disturbing the orbital fossa or its contents.

Entering the Frontal Sinus through the Inferior Surface. —There are many cases where this route is infinitely preferable. It does not allow such good exposure of the sinus, but usually sufficient for all cases; it renders the ethmoidal region very accessible; the operation is followed by little or no deformity (Case V); it is more liable to give rise to inflammable disturbance in the orbital fossa, or interfere with the lachrymal apparatus, if not carefully done. This route is preferable in cases complicated by fistula or orbital tumor.

The preferable incision is that figured in Plate 81, No.

2. It commences opposite the inner canthus, in front of the margin of the orbit, over the nasal process of the superior maxilla. It is carried upward, gently curving outward to meet the eyebrow, and is then carried along the centre of the eyebrow as far as the supraorbital notch. Previous to making this incision, which is carried directly to the bone, the lower half of this inner portion of the eyebrow should be shaved, for the incision should be healed in a week, and thus there will still be a portion of the eyebrow along its whole length, so that the immediate appearance of the patient is not much altered. In time, only a small portion of the incision (about one centimetre) will remain uncovered by hair.

Hæmorrhage may be expected from the supraorbital and angular arteries, which can be troublesome. The periosteum is to be elevated and the flap turned down so as to expose the vicinity of the internal angular process of the frontal bone (Plates 1, 5, 9). The field of operation should be made perfectly dry, and no further hæmorrhage need be expected from the external wound. The pulley of the external oblique muscle is liable to be reflected with the periosteum, but this does not seem to affect the position or motion of the eyeball.

By means of a chisel a small opening is to be made through the orbital portion of the floor of the sinus, just above the internal angular process of the frontal bone, in the line of the margin of the orbit, which separates the anterior from the inferior surface of the sinus. The bone here is thinner than on the anterior surface and quite easily perforated. The opening into the sinus should be large enough to admit the examining probe, which is made to perforate the lining mucous membrane. If there is an empyema of the sinus, pus will be seen coming out of the exploratory opening, otherwise the natural inference is that the sinus is not much affected and that the pus originates in the anterior ethmoid cells, provided the antrum, as a primary source, has been eliminated. If only the ethmoid cells are involved, we are in a very favorable position to treat them.

The examining probe, now in the sinus, is passed in all directions in order to ascertain its shape and size, so that we may know where it will be safe to work. The exploratory opening should now be enlarged so as to be somewhat oval in shape, with the long diameter vertical, and measuring not over fifteen millimetres. This opening corresponds to a portion of the inner wall of the orbital fossa, including, for the most part, the orbital portion of the floor of the sinus at the internal angular process of the frontal bone, a part of the upper end of the lachrymal bone, and extending in front as far forward as the posterior border of the nasal process of the superior maxilla, and posteriorly as far as the os planum of the ethmoid. The situation of this opening is such that no deformity will result, as it is on a plane at right angles to and posterior to the broad fibrous diaphragm, containing the tarsal cartilages, which stretches across the margin of the orbit. The lachrymal apparatus will not be injured, for the upper portion of the lachrymal sac will be reflected from the bone with the soft parts. This bony opening will generally be sufficient to enable the operator to be certain that the sinus has been cleared of all septa and hypertrophies.

So much for the preliminary portion of the operation, which consists in entering the sinus either through the anterior or inferior walls, and we are now ready to perform the most important step in the operation. This consists in the removal of the entire nasal portion of the floor and thorough curetting the anterior ethmoid cells, and thus establishing as large a communication with the nasal fossa as possible.

If the sinus has been entered through the anterior wall, it should be our aim during the operation to avoid entering the orbit through the vicinity of the lachrymal bone or os planum. A small probe should be passed through the ostium frontale into the nose and left in position as a guide. A study of the anatomical relations will show that it is not safe to force instruments directly backward on account of the

danger of entering the cranial cavity (Plates 9, 40, 51, 53). The general curvature of the posterior surface is fairly constant and regular (Plate 51), so that any sudden interruption in this curvature is suggestive of the presence of a frontal bulla or ethmoidal cells crowding into the posterior angle of the sinus. It will be safe to break through these cells with the instrument directed downward, inward, or somewhat backward. The contour of the orbital wall of the sinus is very regular as it passes down to become the internal wall of the orbital fossa (Plates 20, 57, 65), and this regularity is a sufficient guide against entering the orbital fossa. It is our aim to remove as much of the nasal portion of the floor of the sinus as possible in order to establish the best drainage. The lateral anatomical limits are the nasal septum internally, and the downward prolongation of the orbital portion of the floor of the sinus externally (Plates 13, 20). Anteriorly we are limited by the thick bony ring around the hiatus frontale, where the frontal bone articulates with the nasal bone and nasal process of the superior maxilla (Plates 13, 15, 63). Posteriorly there is no immediate hinderance after we reach the posterior angle of the sinus, for here we come upon the anterior ethmoid cells, and continue backward under the plane of the cribriform plate to the posterior ethmoid cells (Plates 13, 16, 17, 51, 77, 88). Hence, from the vicinity of the ostium frontale, in which the probe has been placed as a guide, it will be safe to perforate the floor of the sinus directing instruments downward, backward, or inward. The best instruments are small curettes of different sizes, both curved and straight, and also small chisels. It was discovered on the cadaver that the fifth finger could be introduced into the anterior nares almost without exception beyond the second joint (which measures five centimetres in circumference), so that the tip of the finger reached the body of the sphenoid bone. Thus the nasal cavity could be explored and the movement of the curette directed to immense advantage. This procedure was carried out in Case V with

perfect ease. The finger should be lubricated with sterilized oil or vaseline.

In the early attempts to overcome the frontal or ethmoidal suppuration the anterior extremity of the middle turbinate has probably been removed (Plate 30), but if it remains, it will be broken away by the curettes. All the anterior ethmoidal cells should be curetted away as thoroughly as possible, and it will do no harm if some of the posterior cells are injured. The finger itself may break up some bony partitions as well as serving as a guide for the curette passed in through the external opening. Practically this operation consists in removing the greater part of the lateral mass of the ethmoid, which fills in the hiatus frontale, with a comparatively small external opening and the fifth finger in the anterior nares. Meanwhile no blood has reached the pharynx on account of the tampon. All septa in the frontal sinus should be broken down, and as a final act the lining mucous membrane should be thoroughly curetted. The opening into the nose is such that no drainage-tube will be required, and the external wound should be closed without drainage and protected with a sterile dressing. The nose should be packed with iodoform gauze for twenty-four hours.

Where the sinus has been entered from the inferior wall it is somewhat easier to reach the ethmoid cells, but in general the same directions are to be followed, as when operating through the anterior wall. The sinus is not so well exposed, but all septa can be destroyed and the nasal portion of its floor removed, so as to establish perfect drainage. The posterior ethmoid cells, also, are very accessible by this route. No nasal drainage-tube will be needed, and the external wound is to be closed absolutely.

In every instance we must consider whether the antrum is free or has become involved in the suppurative process primarily, or is acting as a reservoir for pus coming from above. In the early examinations it is well to determine as accurately as possible the condition of the antrum, but con-

clusions can be verified just before the operation by the introduction of a needle into the cavity through the inferior meatus. If the anterior ethmoid cells are involved, it is common to find pus in the antrum. If pus is found in the antrum, it is well to be certain that there will be a sufficient aperture for drainage. Operations on the cadaver show that it is very easy for the curette to enter the antrum when destroying the upper part of the uncinate process, so that, intentionally, where we find pus in the antrum, it is well to make a large opening through the middle meatus. The antrum may call for special treatment (Lothrop, "Empyema of the Antrum of Highmore," *Boston Medical and Surgical Journal*, May, 1897), which does not concern us at this time.

After-Treatment.—The treatment of the external wound offers nothing peculiar. There will be more or less œdema of both eyelids, which will subside in a few days.

The gauze in the nasal fossa is to be removed in about twenty-four hours. On account of the large opening into the sinus, drainage will be perfectly free. The lower portion of the nasal fossa can be irrigated two or three times a day, but it is well not to force fluids up into the sinus for a few days, until the external wound has become united. A warm 2-per-cent. boric acid solution is the most satisfactory. An efficient apparatus for irrigation consists of a slender S-shaped canula, bent so as to pass from the anterior nares, attached to a rubber tube, which in turn is fastened to a barrel syringe with a capacity of at least 100 cubic centimetres. The patient can readily be taught to use this apparatus. At the time of operation all fragments are to be removed from the nasal fossa as well as possible, but some will remain, which can be trimmed later by means of the snare and forceps.

For the reason that we are dealing with a region already infected at the time of operation, it is not surprising if the external wound should fail to unite at once throughout its whole extent, and a fistula result. If, however, free nasal drainage has been established, such a fistula will not persist for a long time.

Report of Cases.

The following cases have been selected to serve as types of acute and chronic inflammatory processes involving the frontal sinus, complicated or not by extension in various directions. They are presented only in moderate detail.

Case I.—*Acute Inflammation in the Frontal Sinus followed by Resolution.*—J. T. E. had just passed through an attack of acute coryza of average severity. Seven days later he began to have pain in the right frontal area, which increased in severity so as to be unendurable. It was relieved by no sort of internal medication. The frontal area was very tender on palpation, and there were no intranasal symptoms referable to the frontal sinus.

A tampon of cotton, saturated with a 4-per-cent. solution of cocaine, was applied as high as possible under the middle turbinate bone, and removed after a few minutes.

During the day the patient sprayed the nose with an oily solution of menthol. The pain continued for thirty-six hours, and then rapidly decreased, followed by a considerable discharge from the right nostril. This continued for a few days only. One week after there was no further trouble, nor has there been any recurrence.

This case is an example of the extension of an acute inflammatory process from the nasal cavity to the frontal sinus, with practically a spontaneous resolution. Such cases are of common occurrence.

Case II.—*Acute Inflammation in the Frontal Sinus of Marked Severity becoming Chronic.*—Miss A., seventy-five years of age, while under treatment for a surgical affection, suffered from an attack of influenza. Following immediately after the onset of acute nasal inflammation, symptoms of acute inflammation referable to the left frontal sinus, arose.

These symptoms were very severe and lasted two weeks. Meanwhile there was much seropurulent discharge from the left nostril, and oftentimes containing more or less blood. At the end of three weeks all the subjective symptoms had disappeared, but the nasal discharge continued. Eight months later the same objective symptoms persist; there is some tenderness

over the frontal sinus, but she has no pain. Her age and physical condition contraindicate operative interference.

CASE III (Plate 83).—*Mucocele of Left Frontal Sinus, becoming a Chronic Empyema of the Frontal Sinus and Anterior Ethmoid Cells: Secondary Involvement of the Antrum.*—I am indebted to Dr. J. W. Farlow, of Boston, for the privilege of publishing this case, under whose treatment the patient has been for the last year.

R. M., twenty-five years of age, baker, has had a swelling in the upper inner angle of the left orbital fossa for the last ten years. He states that it first appeared while suffering from scarlet fever. It has increased slowly without ever causing acute symptoms, although it is occasionally a little tender. It was incised once with a negative result. He is not subject to coryza, and has never had any nasal discharge. At times the tumor is a little smaller than usual, and then he has observed that its surface is rough and irregular.

The tumor has always obstructed the tear-duct, so that tears escape over the cheeks. The eye soon became dislocated, and continues to remain so, but vision has not been affected in any way.

Nearly a year ago the patient first appeared for treatment, on account of a sudden increase in the size of the tumor, accompanied by pain and tenderness and œdema of the eyelids. The size of the tumor at this time is shown in Plate 83.

Examination reveals a tumor about the size of a robin's egg, continuous on the periphery with the frontal bone above, the lachrymal bone in front, but posteriorly its outline is lost in the orbital fossa. Its surface is soft and fluctuating in places, alternating with thin bony areas, which extend from a protruding bony periphery. "Egg-shell crackle" could be detected here and there.

Intranasal examination shows that the mucocele has pushed the middle turbinate against the septum of the nose. The eyeball is dislocated downward, forward, and outward, so that it is in close proximity to the malar bone, but neither subjective nor objective symptoms have resulted therefrom. There are no particular constitutional symptoms.

After removing a portion of the middle turbinate bone under cocaine anæsthesia, a polypoid mass appeared, which was found

to consist of a thin sac containing about an ounce of thick viscid fluid, which escaped from the anterior nares. This circumstance was followed by a diminution in the size of the external tumor, and relief from pressure symptoms.

From time to time various intranasal operations have been performed in order to establish free drainage from the frontal sinus and ethmoid cells. After the removal of the original contents of the mucocele the discharge became purulent, as is characteristic in these cases, and has remained so ever since. The external tumor has decreased very much, and is marked by an irregular bony outline. The eyeball still remains close to the malar bone, and external palpation would suggest that the ethmoid cells are involved in the suppurative process.

On account of undue prominence of the anterior wall of the superior maxilla the antrum was aspirated through the inferior meatus, and found to contain pus. A tooth was extracted and the antrum irrigated through the alveolus. There would seem to be a general association of the left accessory sinuses.

The external appearance of the patient has been greatly improved, and the amount of discharge from the nose has decreased very much. The patient is still under Dr. Farlow's treatment. This case has just been reported in detail before the American Laryngological Association.

CASE IV.—*Suppuration in all the Accessory Sinuses of the Left Nasal Fossa, with Caries of the Frontal and Superior Maxillary Bones.*—A. G., twenty-eight years old, has suffered for the last eleven years from extensive caries in different facial bones of syphilitic origin. She has undergone several operations at the hands of different surgeons with little or no improvement. Extreme antisyphilitic treatment has been of no avail.

When first seen there was marked deformity as the result of inflammatory œdema (Plate 84), and this swelling never decreased. There was profuse discharge of pus into the middle meatus. At times the whole left side of the face was painful, with tenderness localized particularly over the facial wall of the antrum and the inferior surface of the frontal sinus. She had abscesses in the vicinity of both lachrymal sacs, which were incised, and on the left side the tears no longer passed normally into the nose, but escaped over the cheek, and had given rise to a very troublesome chronic eczema.

All the teeth of the upper jaw had been removed, and she had undergone the canine and alveolar operations, but still the antrum was full of pus, as demonstrated by the exploratory needle. On account of the failure of these methods to overcome the antrum suppuration, and the great chronicity of the case, the naso-antral septum under the inferior turbinate bone was removed, as previously referred to (*Boston Medical and Surgical Journal,* May, 1897). Patient recovered well from the operation, and at the end of about four weeks the antrum irrigations were free from pus. Nevertheless, the facial deformity remained unchanged, also the frontal tenderness, and there was a certain amount of pus referable to the frontal sinus, the anterior ethmoid cells, or both.

The frontal sinus was opened through the anterior wall and a bone-flap turned down, as has been previously described in detail. The nasal portion of the floor of the sinus was carefully removed and the anterior ethmoid cells curetted. On account of the post-nasal tampon there was no annoyance from hæmorrhage. A rubber drainage-tube was inserted leading from the sinus to the anterior nares, and held in position by two fine wire sutures, which also served to retain the replaced bone-flap. Such drainage is no longer considered necessary, for later experience has demonstrated that the enlarged opening into the sinus is ample. On account of the extensive persistent swelling over the malar and superior maxillary regions, an exploratory incision was made below the malar bone, in order to discover necrosed bone, but none was found.

The frontal wound was closed without external drainage and united permanently, except where the wire suture, connected with the drainage-tube, appeared. This fistula healed at the end of about four weeks, and the wound remained permanently closed. There was no depression of the anterior wall of the sinus.

The nasal discharge became gradually less, but the general swelling of the face, present before the operation, remained constant.

Two months after the operation the patient had a rise of temperature with severe headache and other symptoms, which were evidently due to an acute meningitis. This complication proved fatal.

An incomplete pest-mortem examination was allowed, when

it was ascertained that there was a perforation in the posterior wall of the frontal sinus near the external angle. The perforation itself would just admit a small probe, but it was surrounded by an area of carious bone. There was found an acute meningitis, most marked in the left frontal region, and there were several small pus-collections in the cortex of the frontal lobe.

There was a small amount of muco-pus in the frontal sinus, but its walls were smooth, and the enlarged opening into the cavity admitted the little finger. There was firm union in the vicinity of the bone-flap. Death was obviously the result of a meningitis, due to a perforation in the posterior wall of the sinus, which in turn was consequent on a carious process in the bone. In view of the past history this was a syphilitic process. Cultures revealed a mixed infection with a predominance of streptococci. On account of the lapse of time since the operation (two months), and the location of the carious bone, it is fair to assume that the perforation was not of traumatic origin. It was clearly demonstrated that such a plastic bone operation was practicable.

CASE V.—*Combined Empyema of the Frontal Sinus and Ethmoid Cells, with Pus draining into the Antrum: Complete Recovery following the Operation.*—N. R., twenty-six years of age, has been troubled with a suppurative process in the accessory sinuses of the left nasal cavity for the last ten years. The nasal discharge has been profuse most of that time, meanwhile she has suffered from constant headache in the frontal region, which was frequently severe enough to cause her to remain in bed. She states that she was never free from suffering. The pain was referable to the whole left side of the face, particularly in the left frontal area.

Eighteen months ago there appeared a swelling at the upper inner angle of the left orbital fossa accompanied by pain and tenderness, together with swelling of the eyelids and soft parts in the vicinity. These external signs disappeared spontaneously at the end of three weeks, but the pain and discharge remained as before.

About sixteen months ago she was referred, by Dr. J. A. Gordon, of Quincy, to Dr. F. C. Cobb, of Boston. Nasal examination showed the presence of polypi in the left cavity, in addition to a profuse discharge of pus. These polypi were removed by Dr. Cobb, and some time later the anterior extremity of the

middle turbinate. For a time there was a decrease in the amount of pain and discharge, but eventually the general condition remained about the same. It was also discovered that the left antrum contained pus, as demonstrated by transillumination and confirmed by the aspirating needle.

Two months ago the patient was kindly referred to me for radical treatment by Dr. Cobb. The frontal and orbital pain had become more severe of late and the discharge was profuse, but without particular odor. There was marked tenderness at the inferior wall of the frontal sinus, but no swelling. Nasal examination showed nothing beyond the presence of pus escaping above the inferior turbinate, and the absence of the anterior end of the middle turbinate. After ten years of suffering the patient was very willing and anxious to have anything done for her relief, and consented to an external operation.

Operation (ether).—As a preliminary step the antrum was aspirated through the inferior meatus and found to contain pus. The posterior nares were plugged with a gauze tampon. The lower half of the inner portion of the eyebrow was shaved, and the vicinity prepared for operation. The incision already described for exposing the floor of the sinus (Plate 81, No. 2) was made down to the bone, and the flap reflected so as to include the periosteum. Hence, two-thirds of the incision was in the eyebrow, while the inner extremity arched downward towards the inner canthus. The exposed bone included the floor of the sinus near the internal angular process of the frontal bone, the upper portion of the os planum and nasal process of the superior maxilla. Hæmorrhage from the supraorbital and angular arteries was controlled by gauze pressure. After the wound was dry a small opening was chiselled into the floor of the sinus, and on passing through the lining mucous membrane considerable pus escaped. The probe showed the sinus to be of average size. This opening was then enlarged to about ten millimetres in diameter. According to the method described in detail in the previous pages, the nasal portion of the floor of the sinus and the ethmoid cells were carefully curetted. The little finger, introduced through the anterior nares, was of immense value in guiding the curette passed through the external wound, and also served to destroy some of the ethmoid cells. The operation was practically a curettement of the anterior portion of the lateral mass of the

ethmoid. An opening into the antrum was made through the middle meatus.

No drainage-tube was used between the sinus and the nasal cavity, the sinus walls were carefully curetted, and the external wound closed without drainage. The nasal cavity was packed with iodoform gauze through the anterior nares. Absolutely no blood reached the pharynx on account of the postnasal tampon.

On the following day the gauze was removed and no further packing used. With the exception of the extreme inner end of the incision, primary union resulted throughout and remained firm. On account of the free nasal drainage the sinus was not irrigated during the first week, but the nasal cavity was cleansed three times during the day with a 2-per-cent. boric acid solution. At the end of two weeks the fistula had healed and remained so for three weeks, when it reopened for a period of three weeks, and has remained closed ever since.

The pain and headache disappeared at once after the operation and have not returned. Two months after the operation there was not enough discharge for the patient to perceive it. The anæsthesia produced by cutting the supraorbital nerve is gradually disappearing.

Since the first week after the operation the sinus has been irrigated three times daily with a 2-per-cent. boric acid solution. This was performed readily by the patient using a bent canula and barrel syringe. By means of the snare a few polypoid granulations were removed from the ethmoid region. The antrum remains free from pus. The patient has gained considerable weight, is perfectly free from pain, has a cicatrix that is hardly perceptible, and states that she feels perfectly well.

CASE VI.—*Repeated Pus Accumulations in Left Frontal Sinus; Spontaneous Evacuations into Nasal Cavity; Present Absence of Symptoms.*—I am indebted to the kindness of Dr. L. S. Pilcher, of Brooklyn, for the privilege of publishing the following three cases. His records of the cases are as follows:

"T. A. T., male; forty-one years of age; of somewhat delicate constitution. Ten years ago suffered in quick succession from pneumonia, hæmoptysis, and acute articular rheumatism, as a result of which he was an invalid for three years. Prior to this he had suffered for a period of about five years from a chronic nasal catarrh following a severe attack of acute coryza. This

acute attack was attended with special distress between the eyes, and with severe general headache. During the time he was the subject of the pulmonary and rheumatic troubles, and for some years after his recovery from these, he was free from nasal symptoms. However, in 1885, he began to suffer much from frontal and supraorbital headache, affecting the left side especially. Two or three times each winter these would be complicated with severe attacks of acute coryza, attended with a sense of great discomfort and distention between the eyes; the left conjunctiva would become congested, while the right would remain unaffected; there would be severe pain in the left orbit, diffusing itself thence over the forehead and backward to the left side of the head.

"Some of these attacks gradually subsided without any noticeable crisis; at other times, immediate relief to all the symptoms would suddenly occur after a free flow of pus from the left nasal cavity. Again, sudden abundant escape of pus would at times occur, not preceded by acute pain, but only by a variable period of dull distress in the forehead. After these gushes of pus would take place a continuous purulent discharge, amounting to from one to two and one-half ounces daily, would persist for a time, gradually diminishing in quantity, until it ceased altogether. During the winter of 1889 he had an unusually severe and prolonged attack, extending over some months.

"The patient has had no particular treatment for his condition, and his recoveries have been spontaneous. There have been no recent reports from this case."

Case VII.—*Abscess of Left Frontal Sinus with Necrosis of Anterior Wall and Floor of Sinus: Sequestrotomy; Obliteration of Sinus with Cure.*—Dr. Pilcher's record: "Ellen T., aged nineteen years, appeared with a suppurating sinus of the upper and inner part of the left orbit, of which she gave the following history: Ten years previously she had been struck by a stone upon the left frontal eminence, inflicting a wound which healed in three weeks, but from that time she began to suffer from daily headaches. Two years ago a swelling over the left eye appeared, which, however, disappeared again in a few days under local applications. At the end of eighteen months the parts again became swollen and painful. Repeated incisions into the swelling,

with liberation of pus, were made during the months following, resulting finally in the persistent sinus noted above.

"She was referred to me by Dr. Arthur Mathewson, and an exploratory operation under chloroform was performed. After making incisions through the soft parts sufficiently free to expose the margin of the orbit and the surface of the frontal bone, at the inner angle of the orbit, two bony sequestra were exposed, lying loosely in the tissues. These sequestra were removed.

"Examination of these shows that together they compose the anterior and inferior walls of the frontal sinus. The exposed shallow cavity of the sinus was shut off from the nasal cavity and its mucous membrane hypertrophied. This was curetted and the skin replaced so as to obliterate the sinus. Rapid repair took place with very little deformity."

CASE VIII.—*Chronic Frontal Empyema with Orbital Tumor and Fistula; Operation for Obliteration of Sinus followed by Recovery.*—Dr. Pilcher's records: "S. B. S., sixty years of age, an oysterman, had a well-marked tumor at the inner angle of the left orbit, extending upward and inward to the midfrontal region (Plate 89). At the most prominent part of the tumor was a fistulous opening leading upward into a large cavity.

"For ten years or more he had had some nasal catarrh with occasional discharge of offensive pus and crusts from his nose without subjective symptoms. Four years ago he first noticed a swelling at the inner angle of the orbit, which, without tenderness or redness or subjective symptoms, slowly increased to the size of a small hen's egg, pushing the eye outward so as to cause diplopia. Within a year the tumor began to discharge into the nostril. At the Brooklyn Ear and Eye Hospital repeated incisions into the tumor caused the evacuation of pus, but not the collapse of its walls, hence the case was referred to me, when the following operation was performed:

"Free incision of the fistulous track having been done, an opening of some size through the anterior wall exposed the frontal sinus, which was greatly dilated. No communication was found with the nasal cavity. The posterior wall of the sinus had been absorbed over an area about one centimetre in diameter, bringing the sac of the abscess into immediate juxtaposition to the dura mater at that point. Hence it was determined to obliter-

ate the sinus on account of the risk of further trouble following attempts to preserve it and restore nasal communication.

"The whole anterior wall of the sinus was removed, the mucous membrane thoroughly curetted away, and the skin-flaps replaced and retained by compress. Primary adhesion of much of these flaps was secured, the remainder became healed by granulation with limited suppuration. A fistula persisted for some time, which finally became healed."

CASE IX.—*Abscess of Frontal Sinus; Occlusion of Ostium Frontale; Necrosis with Persistent Fistula.*—This case occurred in the practice of Dr. J. C. Munro, of Boston, and he has kindly allowed me to publish these notes:

Jos. C., Italian, sixty years of age. About one year ago there appeared a swelling in the upper inner angle of the right orbit, which was red, tender, and painful. This ruptured spontaneously, discharged pus, and a fistula resulted, persisting after an attempt to overcome it by operation.

When first seen by Dr. Munro there was a small discharging sinus at the inner angle of the orbit; there was œdema of the upper eyelid, with apparently some dislocation of the eyeball. The probe reveals the presence of necrosed bone. Antisyphilitic treatment has been of no avail. There was no nasal discharge.

Operation (ether narcosis).—Vertical incision at inner angle of orbit extending to frontal bone. Fragments of necrosed bone were removed from the vicinity of the ethmoid region, and a small perforation was discovered leading through the inferior wall of the frontal sinus. All of these openings were enlarged, the necrosed fragments removed, and the wound packed with gauze. The opening was made into the nasal fossa. The usual amount of œdema followed the operation, together with some conjunctivitis, both of which subsided in due time. Two months later there still remained a granulating area. Patient was lost sight of for a month, when he returned with a loose fragment of bone appearing at the old wound. Under ether a sequestrum of bone, tapering at one end, one and one-half inches long, and half an inch wide, was removed. This fragment of bone seemed to be in the nature of a sequestrum originating in the frontal sinus, and the remaining cavity of the sinus was apparently walled off in all other directions. The wound closed rapidly so that a very

small fistula remained. Meanwhile there have been no nasal symptoms.

From time to time this fistula has closed, but has never remained permanently healed. This case shows that under careful treatment it has been impossible to obliterate the frontal sinus, either on account of its size or the presence of an obscure piece of necrosed bone. The absence of nasal discharge is proof of the occlusion of the ostium frontale, hence, if there is any cause for the persistence of the exudate, the fistula will fail to heal. Under the circumstances it would seem that the only alternative would be to establish nasal drainage in the manner already described.

CASE X.—*Frontal Empyema following Trauma; Uncomplicated Recovery.*—The following case occurred in the practice of Dr. F. B. Lund, of Boston, and to him I am indebted for the following notes:

"A boy of twelve years was operated for a compound depressed fracture of the frontal bone in the vicinity of the frontal sinus. All wounds healed, and he made an apparently good recovery. Two months later he returned for treatment on account of two sinuses which had appeared at either end of the nasofrontal suture. There was considerable swelling of the subcutaneous tissue and a moderate amount of seropurulent discharge from the sinuses. A probe passed into the left opening in such a way that the end was evidently in the frontal sinus, the resistant bony walls of which could be detected, but there was no evidence of necrosed bone. The right sinus connected with the left one under the skin. There was some left nasal discharge.

"*Operation* (ether narcosis).—The left eyebrow being shaved, an incision was made at its inner end running horizontally outward, down to the bone, and, on elevating the skin, it was found that the anterior wall of the left frontal sinus had been fractured into three pieces and driven inward; these fragments of bone were in a healthy condition.

"The anterior wall of the sinus was removed, showing the absence of hypertrophied or polypoid mucous membrane. A probe was passed through the ostium frontale into the nasal cavity, and the natural opening enlarged by means of a fine curette. A drain of half a dozen strands of silkworm gut passed down to the nares, but this was pulled out by the patient on coming out of ether. The sinuses in the skin were curetted, and

the incision over the frontal sinus closed without drainage. The wound healed by first intention and the sinuses closed in a few days. The after-treatment for the nasal cavity consisted in three or four daily irrigations with a normal salt solution. A perfect recovery resulted."

This case evidently was not complicated by suppuration in the anterior ethmoid cells. Restoration of nasal drainage was sufficient for recovery, without attempting to obliterate the sinus.

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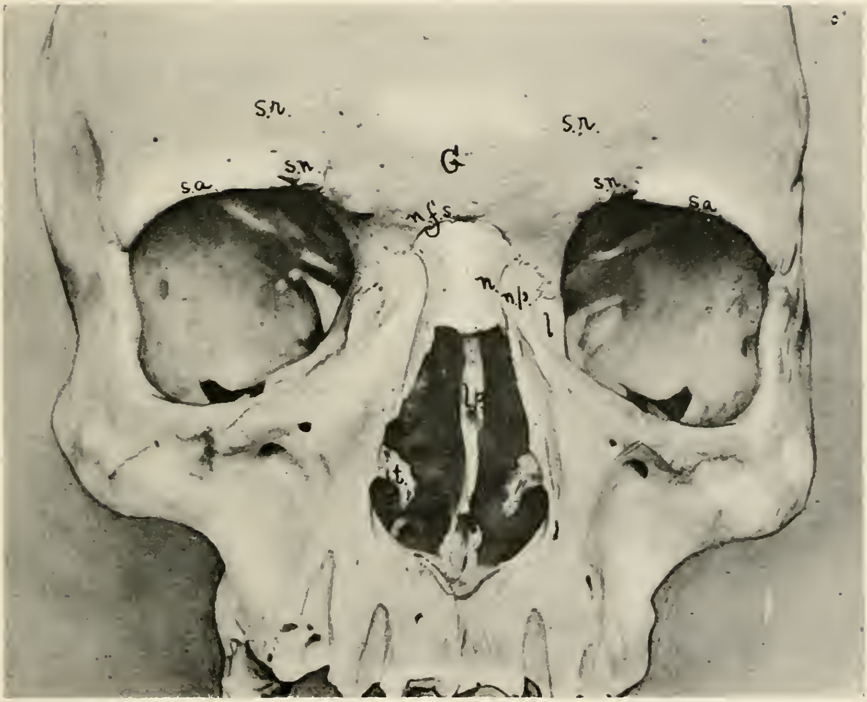
Plate 1.



ANTERIOR VIEW OF SKULL.

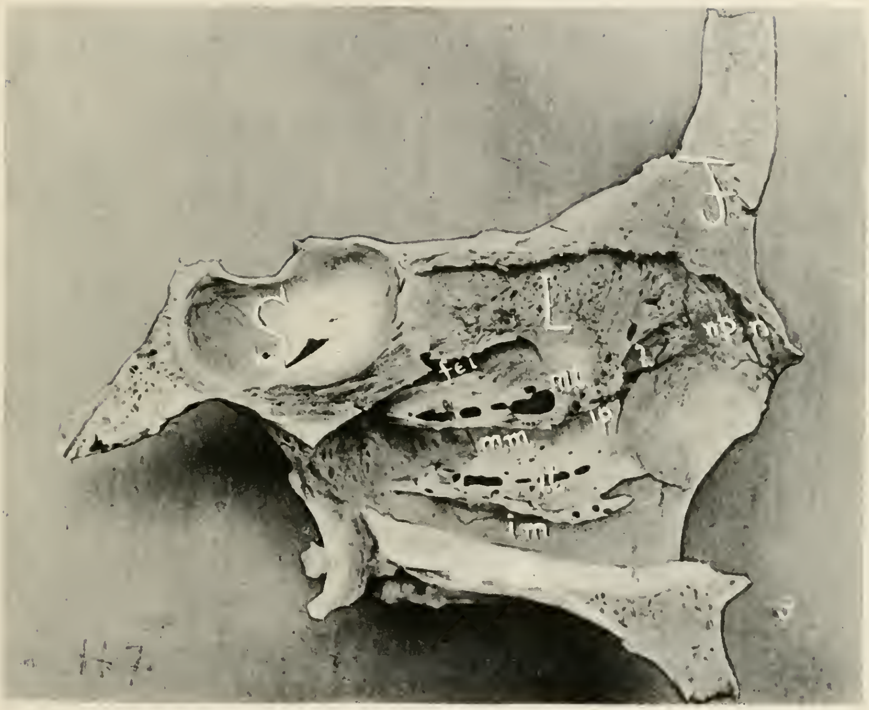
g. Glabella or nasal eminence. *s.r.* Superciliary ridge. *s.a.* Supra orbital arch. *s. n.* Supra orbital notch or foramen. *n.* Nasal bone. *n.p.* Nasal process of superior maxillary bone. *l.* Lachrymal bone. *n.f.s.* Naso-frontal suture. *i.t.* Inferior turbinate bone. *l.p.* Lamina perpendicularis.

Plate 2.

SAGITTAL SECTION TO RIGHT OF NASAL SEPTUM, SHOWING LATERAL WALL OF NASAL FOSSA. TURBINATE BONES UNDISTURBED.

F. Frontal sinus. S. Sphenoidal sinus. *i.t.* Inferior turbinate bone. *m.t.* Middle turbinate bone (inferior ethmoidal turbinate bone). *3 and 4.* Middle and superior ethmoidal turbinate bones. *c.g.* Crista galli. *n.* Nasal bone. *i.m.* Inferior meatus. *m.m.* Middle meatus.

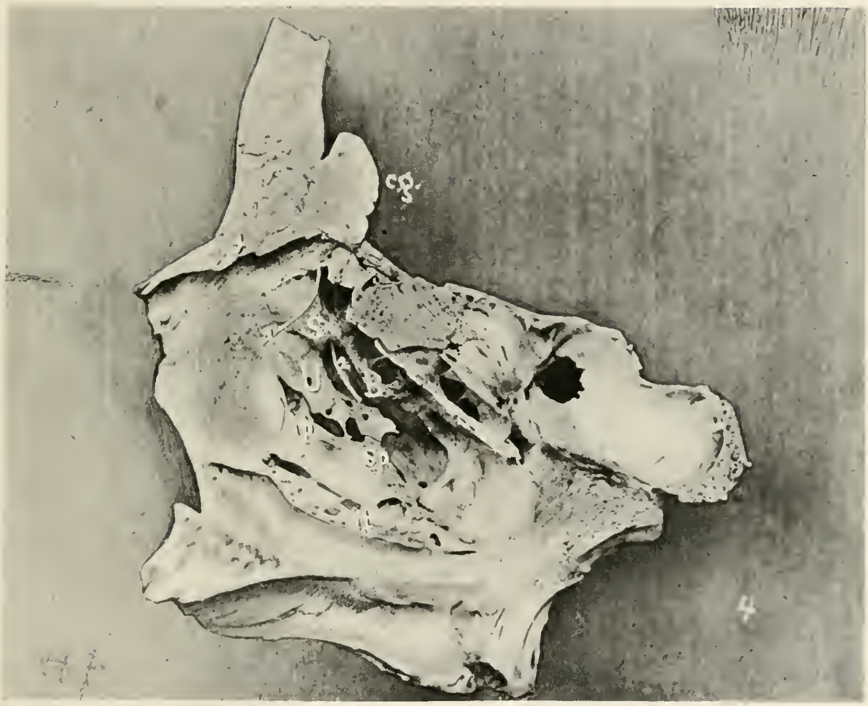
Plate 3.



BONE. LEFT NASAL FOSSA, EXTERNAL WALL, SHOWS ATROPHY OF BONE IN AGED.

i.t. Inferior turbinate. *m.t.* Middle turbinate. *S.* Sphenoidal sinus. *i.m.* Inferior meatus. *m.m.* Middle meatus. *f.e.i.* Fissura ethmoidalis inferior. *L.* Internal wall of lateral mass. *n.p.* Nasal process of superior maxilla. *l.* Lachrymal bone. *l.p.* Lachrymal process of inferior turbinate bone. *n.* Nasal bone. *F.* Frontal bone.

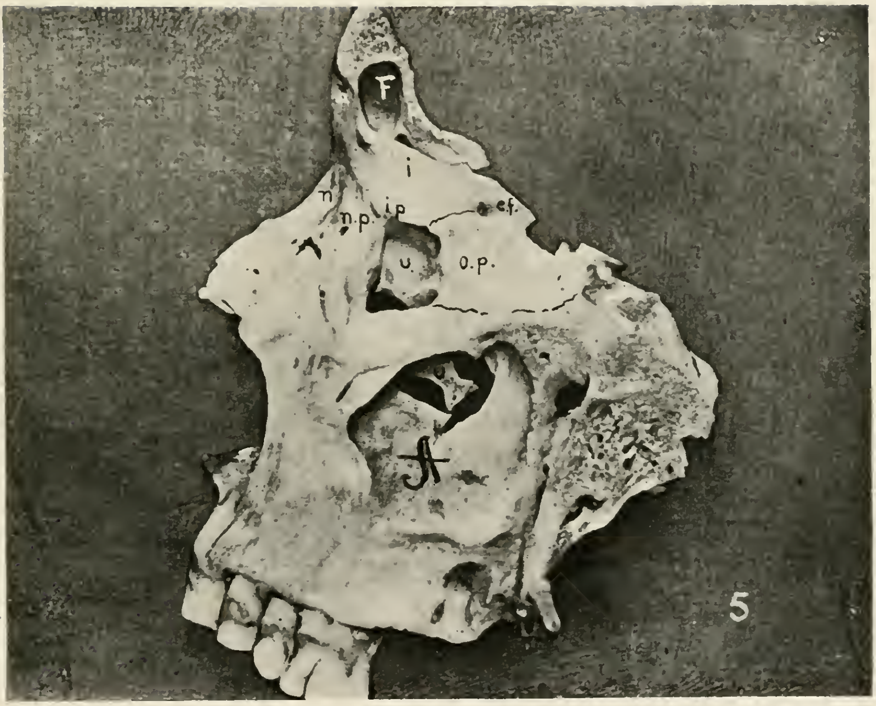
Plate 4.



BONE. RIGHT NASAL FOSSA, EXTERNAL WALL, MIDDLE TURBINATE BONE REMOVED ALONG DOTTED LINE.

f. Nasal process of frontal bone. *i.t.* Inferior turbinate. *l.p.* Lachrymal process of inferior turbinate. *e.p.* Ethmoidal process of inferior turbinate. *U.* Uncinate process of ethmoid bone. *B.* Bulla ethmoidalis with its ostium just above. *S.* Septum between Uncinate process and Bulla. *1.* Probe passed into frontal sinus through turbinate fossa. *2.* Probe passed through Hiatus Semi-lunaris, into Infundibulum to Anterior Ethmoid Cells. *cg.* Crista galli.

Plate 5.



BONE. LEFT ORBITAL FOSSA, INNER WALL, LACHRYMAL BONE REMOVED.

o.p. Os Planum. *e.f.* Anterior ethmoidal foramen. *F.* Frontal sinus. *a.* Its anterior wall. *p.* Its posterior wall. *i.* Orbital portion of its inferior wall *n.* Nasal bone. *n.p.* Nasal process. *A.* Inner wall of Antrum of Highmore. *i.p.* Internal angular process of frontal bone. *U.* Uncinate process.

Plate 6.

BONE. CORONAL SECTION THROUGH POSTERIOR ANGLES OF FRONTAL SINUS' LOOKING INTO THE SINUS FROM BEHIND.

F. Frontal sinus. *p.* Its posterior wall. *i.* Its inferior wall. *c.g.* Crista galli. *n.s.* Small portion of nasal septum. A. Antrum. *m.t.* Line of insertion of anterior extremity of the left middle turbinate on the nasal process of the superior maxilla. *a.a.a.* Anterior ethmoidal cells. Arrow showing course of nasal duct.

Plate 7.

Internal Wall of Left Orbital Fossa with Lachrymal Bone Removed, Showing Upper Portion of Uncinate Process and Bony Septa, which Complete Certain Anterior Ethmoid Cells when the Lachrymal Bone is in Situ.

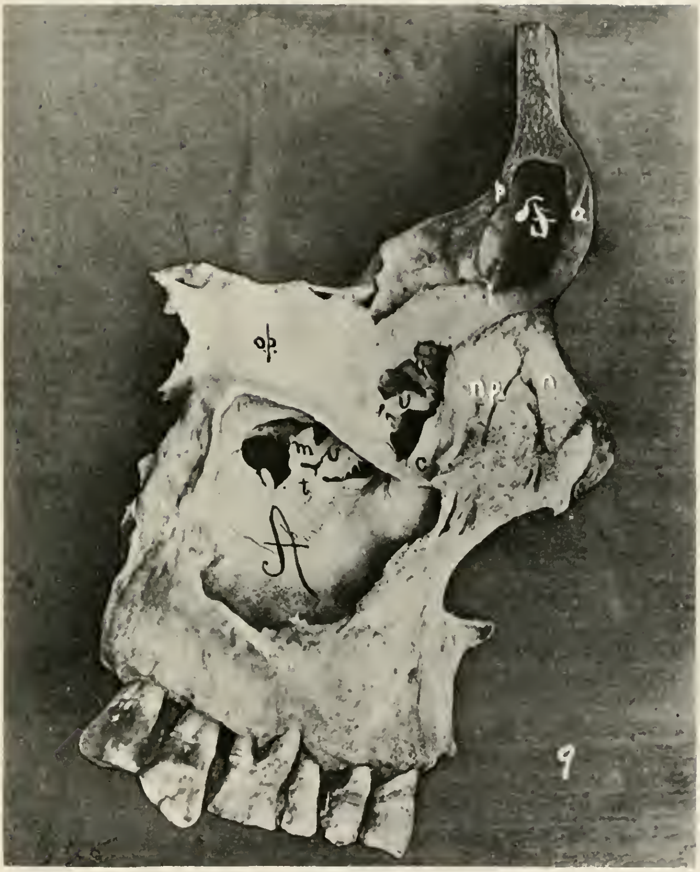
u.u.u. Uncinate process, and incomplete ethmoid cells.

Plate 8.

BONE. RIGHT NASAL CAVITY, EXTERNAL WALL, MIDDLE TURBINATE BONE REMOVED ALONG DOTTED LINE.

B. Ethmoid Bulla. U. Processus Uncinatus. *m.* Its maxillary process. *l.* Lachrymal bone. *f.e.i.* Fissura Ethmoidalis Inferior. *i.t.* Inferior turbinate. *1.* Probe through turbinate fossa to frontal sinus. *2.* Probe through Hiatus Semilunaris and infundibulum to anterior ethmoid cells situated between lachrymal bone and upper extremity of Uncinate process. *f.* Nasal process of frontal bone. A. Agger Nasi. *s.* Septum between Uncinate and Bulla. *n.p.* Nasal process of superior maxilla. *i.m.* Inferior meatus.

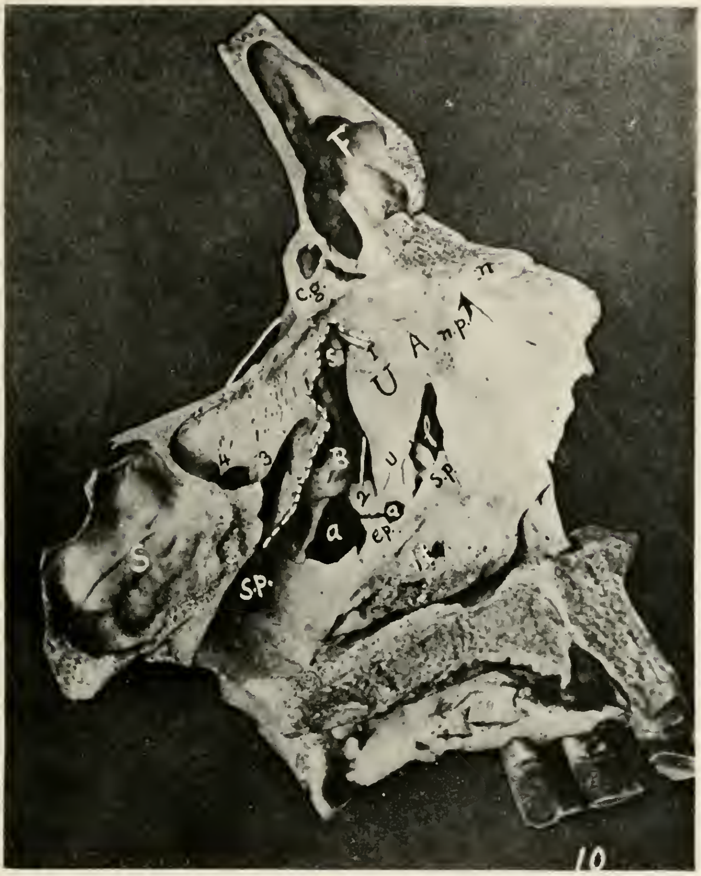
Plate 9.



BONE. INNER WALL, RIGHT ORBIT, LACHRYMAL BONE REMOVED.

F. Frontal sinus. *a.* Superciliary ridge on anterior wall. *p.* Posterior wall. *i.* Inferior wall, at internal angular process of frontal bone. *n.* Nasal bone. *n.p.* Nasal process of superior maxilla. *u.u.u.* Uncinate process with septa and incomplete ethmoidal cells. *m.* Maxillary process of uncinate, closing ostium maxillare. *t.* Turbinate process of uncinate. *o.p.* Os Planum *c.* Nasal canal. *A.* Internal wall of Antrum.

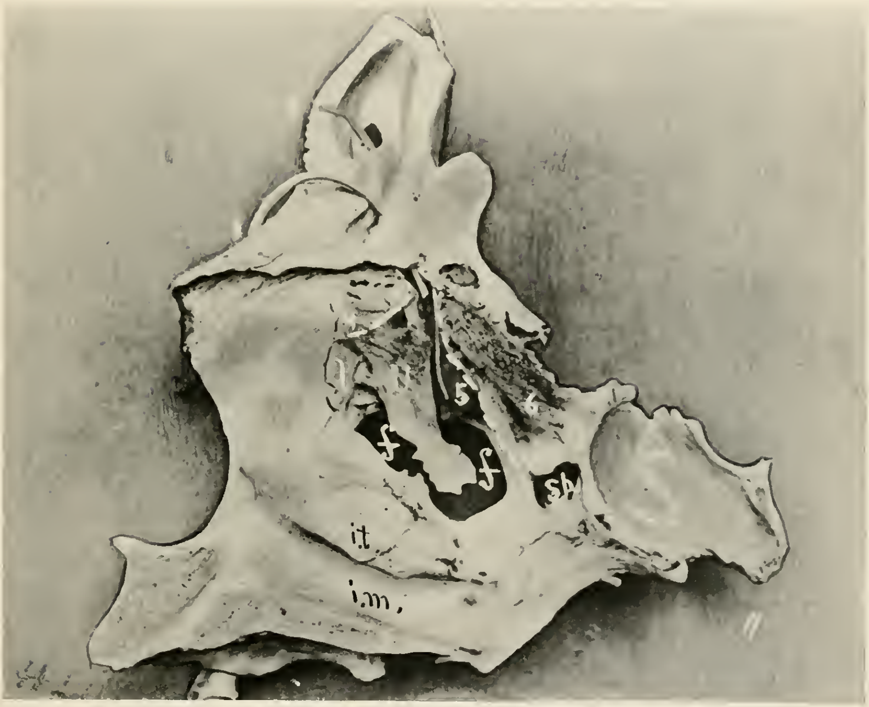
Plate 10.



BONE. LEFT NASAL FOSSA, EXTERNAL WALL, MIDDLE TURBINATE REMOVED ALONG DOTTED LINE, AND ALSO THE LACHRYMAL BONE REMOVED, (*l*).

1. Probe through turbinate fossa to frontal sinus. *2.* Probe through Hiatus Semi lunaris and Infundibulum to anterior ethmoid cells, situated between uncinate process and bulla ethmoidalis. *l.* Space completed by nasal aspect of lachrymal bone, forming thereby a portion of the bony external wall of the nasal fossa. *U.* Uncinate process (Fig. 2 on its maxillary process). *B.* Ethmoid Bulla, its ostium just above. *i.t.* Inferior turbinate. *s.p.* Its lachrymal process. *e.p.* Its ethmoid process. *A.* Agger Nasi. *F.* Frontal sinus, with septa. *c.g.* Crista galli hollowed out by a diverticulum. *S.* Sphenoidal sinus. *s.p.* Spheno-palatine foramen. *a.a.* Bony fontanelles leading to Antrum. *o.m.* Ostium maxillare. *s.* Septum between Uncinate and Bulla. *n.* Nasal bone. *n.p.* Nasal process of superior-maxilla. *3 and 4.* Middle and superior turbinate bones of the ethmoid.

Plate 11.



BONE. NASAL CAVITY, EXTERNAL WALL, MIDDLE TURBINATE REMOVED. SEPTUM BETWEEN UNCINATE PROCESS AND ETHMOID BULLA WANTING SO THAT THE TURBINATE FOSSA AND UPPER END OF INFUNDIBULUM ARE ONE CAVITY.

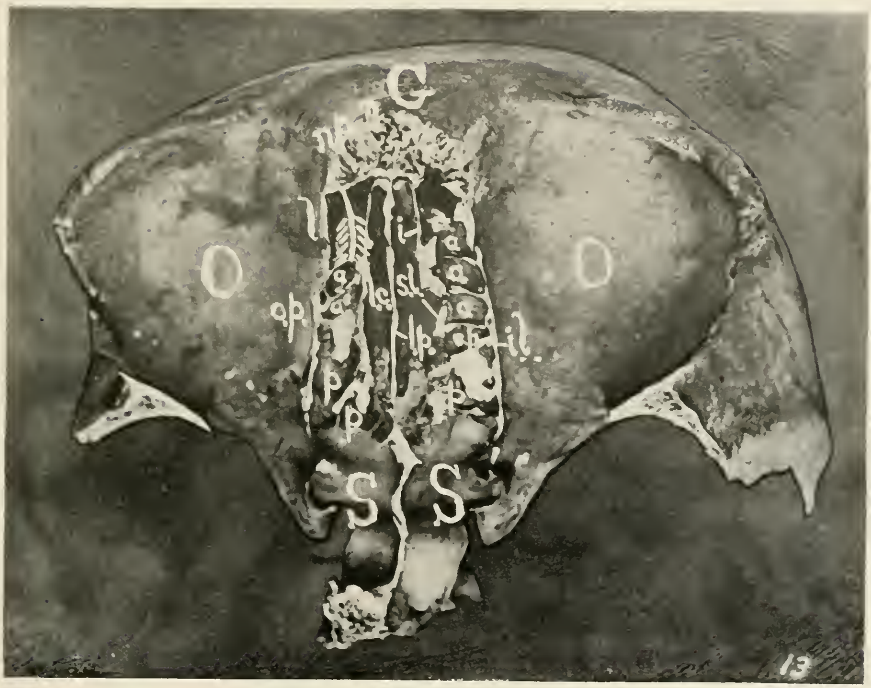
1, 2, 3. Probes in divisions of right frontal sinus leading to the cavity common to the turbinate fossa, and upper end of Infundibulum. *4,4,4.* Dotted line marking insertion of middle turbinate. *5.* Small Ethmoid Bulla. *6.* Superior turbinate. *7.* Spheno-ethmoidal recess. *U.* Uncinate process. *l.* Lachrymal bone. *S.* Sphenoidal sinus. *i.t.* Inferior turbinate. *s.p.* Spheno-palatine foramen. *i.m.* Inferior meatus. *f.f.* Fontanelles leading to Antrum.

Plate 12.

BONE. LEFT NASAL CAVITY, EXTERNAL WALL, MIDDLE TURBINATE REMOVED ALONG THE DOTTED LINE. NO SEPTUM BETWEEN UNCINATE PROCESS AND ETHMOID BULLA, SO THAT TURBINATE FOSSA AND UPPER END OF INFUNDIBULUM ARE ONE CAVITY, INTO WHICH OPENS THE FRONTAL SINUS, AS SHOWN BY PROBE.

s. Septum between"fronal sinuses. B. Ethmoid Bulla. U. Uncinate process. *a*. Agger Nasi. *i.t*. Inferior turbinate. *f.f*. Fontanelles to Antrum. *s.p*. Spheno-palatine foramen. *l*. Lachrymal bone. *l.p*. Lachrymal process of inferior turbinate. *n*. Nasal bone. *n.p* Nasal process of superior maxilla.

Plate 13.



FRONTAL BONE REMOVED AT NASO-FRONTAL SUTURE, INCLUDING LAMINA CRIBROSA AND A PART OF THE LAMINA PERPENDICULARIS, VIEWED FROM BELOW, TO SHOW THE WIDTH OF THE NASAL CAVITY, AND THE AVAILABLE OPERATING SPACE. ARROW PASSING TO FRONTAL SINUS THROUGH HIATUS FRONTALIS.

l.c. Over the location of the lamina cribrosa. *l.p.* Lamina perpendicularis. *a.a.a.* Anterior ethmoidal cells. *p.p.p.* Posterior ethmoidal cells. *S.* Sphenoidal sinus. *O.* Roof of Orbit. *G.* Glabella. *n.* Articulates with nasal bone. *n.p.* Articulates with nasal process of superior maxilla. *l.* Articulates with lachrymal bone. *o.p.* Articulates with os planum. *i.l.* Inferior lamina of orbital portion frontal bone. *s.l.* Superior lamina of orbital portion frontal bone. *i.* Internal wall of lateral mass.

Plate 14.

Lower Portion of Specimen Figured in Plate 13, Showing the Broken Cells of the Lateral Masses. Septum of the Nose Missing. Arrow Passing to Infundibulum from the Direction of the Frontal Sinus.

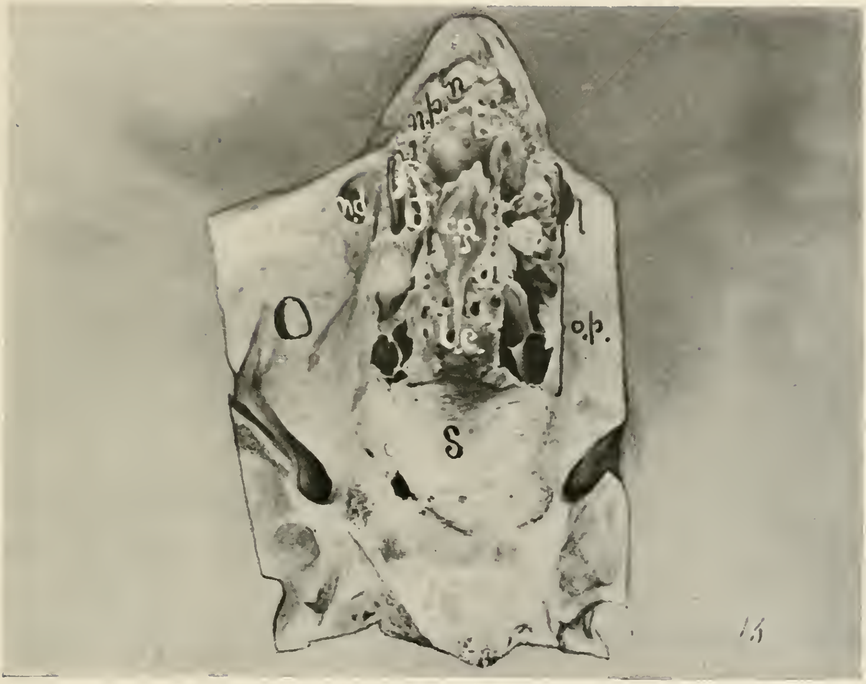
n. Nasal bone. *n.p.* Nasal process of superior maxilla. *l.* Lachrymal bone. *o.p.* Os Planum. *a.a.a.* Anterior ethmoid cells. *p.p.p.* Posterior ethmoid cells. *n.c.* Nasal canal. O. Orbital surface superior maxilla. *i.* Internal wall of lateral mass.

Plate 15.

INFERIOR SURFACE OF TWO FRONTAL BONES, TO SHOW THE VICINITY OF THE HIATUS FRONTALIS.

H. Hiatus Frontalis, looking into frontal sinus. *S.* Inferior border of frontal Septum. *s.n.* Supra-orbital notch. *i.p.* Internal angular process. *e.c.* Roof of an anterior ethmoid cell protruding into frontal sinus from below. *e.n.* Ethmoidal notch formed by the superior laminae of the orbital portion of the frontal bone, which articulate with the lamina cribrosa. *i.l.* Inferior lamina of same. *E.* Space between these two laminae, interrupted by septa forming broken cells, corresponding from before backwards to the anterior ethmoidal cells in the posterior angle of the frontal sinus, anterior ethmoid cells opposite Os Planum, and finally the posterior ethmoid cells. *i.s.* Orbital portion of inferior surface of frontal sinus. *n.* Articulation of nasal bone. *n.p.* Articulation of nasal process of superior maxilla. *l.* Articulation with lachymal bone.

Plate 16.



FRONTAL BONE REMOVED, SHOWING THE BROKEN ANTERIOR AND POSTERIOR ETHMOID CELLS, AND THE THICKENED LINE OF ARTICULATION WITH THE NASAL BONES AND NASAL PROCESSES OF THE SUPERIOR MAXILLAE IN FRONT. PROBE IN LEFT OSTIUM FRONTALE.

c.g. Crista galli. *l.c.* Lamina cribrosa. *n.d.* Nasal duct. *n.* Nasal bone (superior border). *n.p.* Nasal process (Superior border). *l.* Lachrymal bone (Superior border). *o.p.* Os Planum (Superior border). *S.* Roof of sphenoidal sinus. *F.* Nasal portion of floor of frontal sinus. *O.* Inferior surface of orbital fossa.

Plate 17.

SUPERIOR SURFACE OF ETHMOID AND SPHENOID BONES, SHOWING THE BROKEN ANTERIOR AND POSTERIOR ETHMOID CELLS, AND OPENING INTO LEFT SPHENOIDAL SINUS.

A. Anterior ethmoid cells. *P.* Posterior ethmoid cells. *S.* Sphenoidal sinus. *l.c.* Lamina cribrosa. *c.g.* Crista Galli. *n.f.* Naso-frontal canal. *l.p.* Lamina perpendicularis.

Plate 18.

INFERIOR SURFACE OF SAME BONES. ARROW IN LEFT OSTIUM SPHENOIDALE.

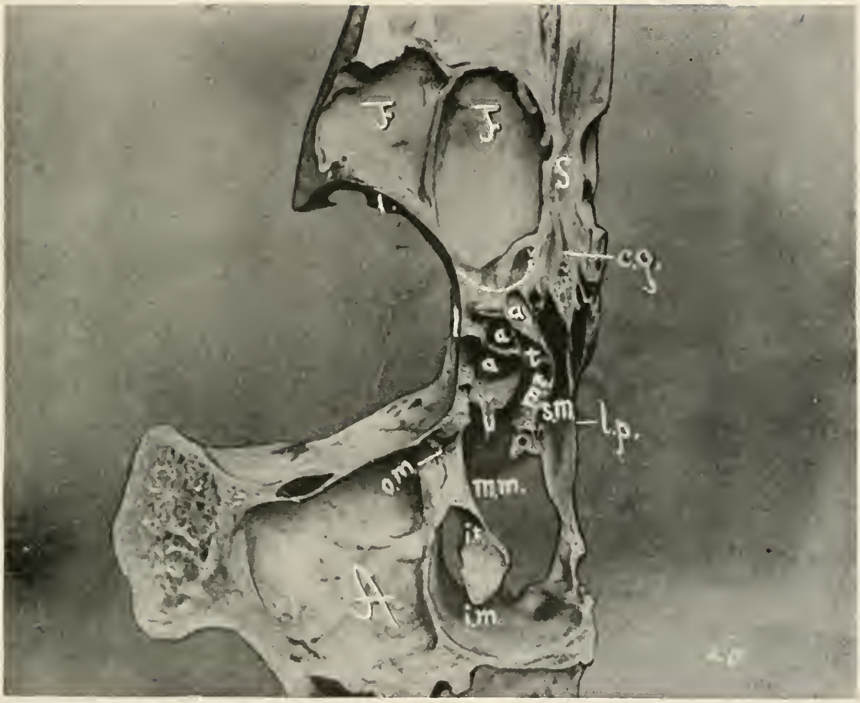
S. Inferior surface of body of sphenoid bone. *m.t.* Inferior border of middle turbinate. *U*. Uncinate process. *n.p.* At point of union of middle turbinate and uncinate process, which articulates with the nasal process of the superior maxilla. *l.p.* Lamina perpendicularis. *s.m.* Superior meatus. *m.m.* Middle meatus. *t.f.* Arrow directed toward turbinate fossa.

Plate 19.

LATERAL VIEW OF A DISARTICULATED ETHMOID BONE.

o.p. Os Planum. *U.* Uncinate process. *m.t.* Middle turbinate. *.p.* Lamina perpendicularis. *c.g.* Crista Galli. *e.c.* Broken anterior ethmoidal cells completed by articulation with lachrymal bone. *i.* Dilated cell like termination of Infundibulum bounded internally by the uncinate process (upper extremity), and externally by the lachrymal bone. *s.m.* Lower border of Os Planum, articulating with orbital surface of superior maxilla. *l.* Articulation of lachrymal bone.

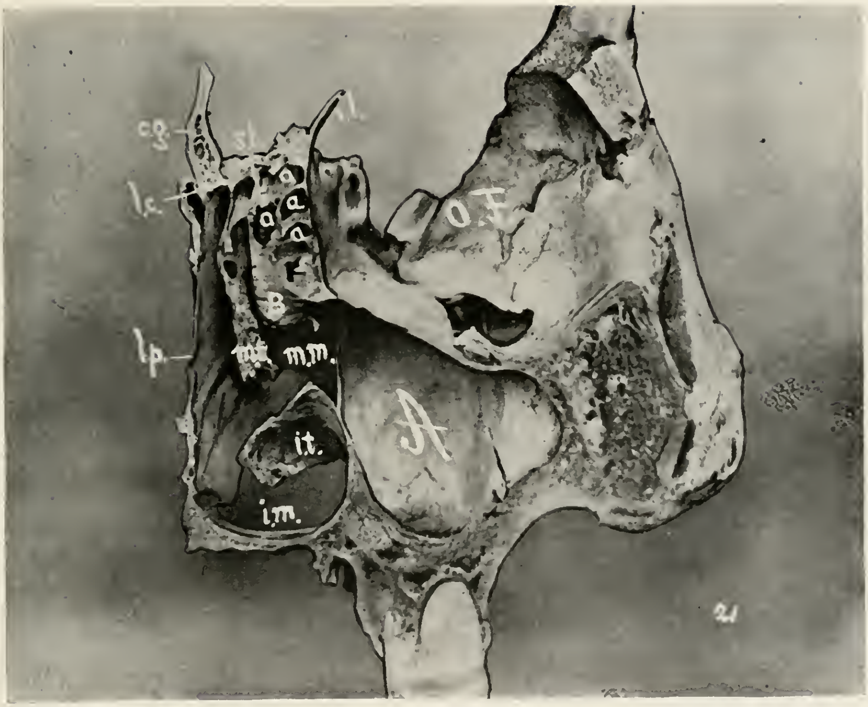
Plate 20.



Bone. Coronal Section Through Ostium Maxillare. Anterior Half. Posterior Wall of Frontal Sinus Removed.

F. An anterior wall of frontal sinus, showing a vertical Septum. *S.* Septum between the frontal sinuses. *i.t.* Inferior turbinate. *m.t.* Middle turbinate. *o.m.* Ostium Maxillare. *U.* Uncinate Process. *l.* Os lachrymale. *t.* Turbinate fossa. *a.a.a.* Anterior ethmoidal cells, internal to lachrymal bone. *A.* Antrum of Highmore. *l.p.* Lamina perpendicularis. *c.g.* Crista Galli. *i.m.* Inferior meatus. *m m.* Middle meatus. *s.m.* Superior meatus. *i.* Inferior wall of frontal sinus (Orbital portion). Dotted line corresponds to nasal portion. See Plate 21.

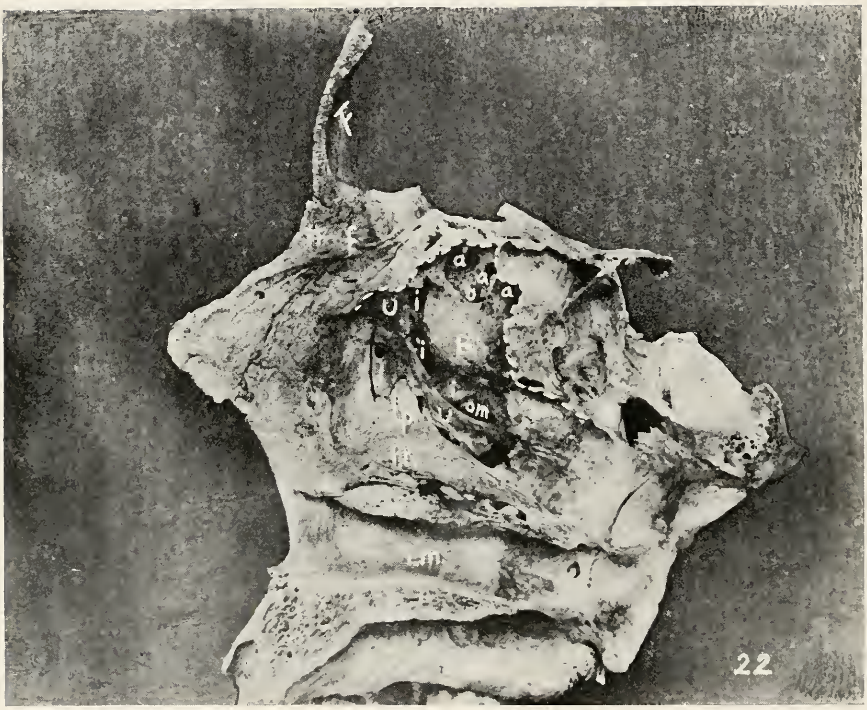
Plate 21.



POSTERIOR HALF OF SAME SECTION.

A. Antrum. *m.t.* Middle turbinate. *i.t.* Inferior turbinate. *B*. Bulla ethmoidalis. *i.m.* Inferior meatus. *m.m.* Middle Meatus. *a.a.a.* Anterior ethmoid cells just above Bulla and internal to lachrymal bone and Os Planum. *i.l.* Portion of inferior lamina of horizontal part of frontal bone. *s.l.* Point of articulation of superior lamina of same, with lamina cribrosa. *O.F.* Orbital fossa. *l.p.* Lamina perpendicularis. *c.g.* Crista Galli. *l.c.* Lamina cribrosa forming roof of nasal fossa.

Plate 22.



BONE. RIGHT NASAL FOSSA, EXTERNAL SURFACE, MIDDLE TURBINATE REMOVED ALONG DOTTED LINE.

B. Bulla ethmoidalis. *U.* Uncinate process, making a complete bony Ostium maxillare, and its anterior border articulating directly with the lachrymal bone, and inferior turbinate bone. *l.* lachrymal bone. *i.t.* Inferior turbinate. *l.p.* Its lachrymal process. *o.m.* Ostium maxillare. *i.m.* Inferior meatus. *a.a.a.* Anterior ethmoid cells above Bulla. *o.* Ostium of Bulla. *i.i.i.* Infundibulum. *F.* Anterior wall of frontal sinus. *f.* nasal process of frontal bone. *n.* Nasal bone.

Plate 23.

LEFT NASAL FOSSA, EXTERNAL WALL, SHOWING PROBE IN COMPLETE BONY OSTIUM MAXILLARE, MIDDLE TURBINATE REMOVED.

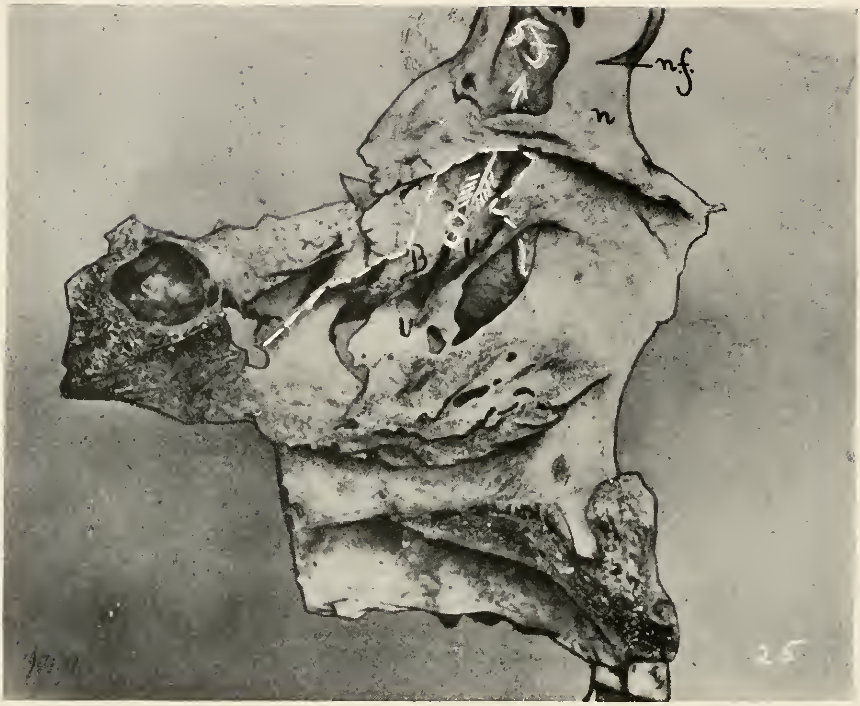
U. Processus Uncinatus. *B.* Bulla ethmoidalis. *i.t.* Inferior turbinate. *l.p.* Its lachrymal process. *l.* Os lachrymale. *o.m.* Ostium Maxillare.

Plate 24.

RIGHT NASAL FOSSA, EXTERNAL WALL.

F. Frontal sinus. *1*. Its flattened anterior surface. *2*. Posterior surface. *3*. Thick ridge formed at naso-frontal articulation, anterior to Hiatus frontalis. *U*. Uncinate process. *B*. Bulla ethmoidalis. *l*. Lachrymal bone. *i.t*. Inferior turbinate. *l.p*. Its lachrymal process. *e.p*. Its ethmoid process. *n*. Nasal bone. *n.p*. Nasal process of superior maxilla. *a.a.a*. Anterior ethmoid cells.

Plate 25.



BONE. LEFT NASAL FOSSA, EXTERNAL WALL. BULLA AND UNCINATE PROCESS VERY CLOSELY APPROXIMATED, AND SO MUCH SO IN THE RECENT STATE, THAT THE HIATUS SEMI-LUNARIS WAS REDUCED TO A SMALL OSTIUM AND THE INFUNDIBULUM CONVERTED INTO A CANAL FOR NEARLY ITS WHOLE EXTENT. DOTTED LINE MARKS REMOVAL OF MIDDLE TURBINATE. FRONTAL SINUS VERY LARGE WITH PROTRUDING SUPERCILIARY RIDGE.

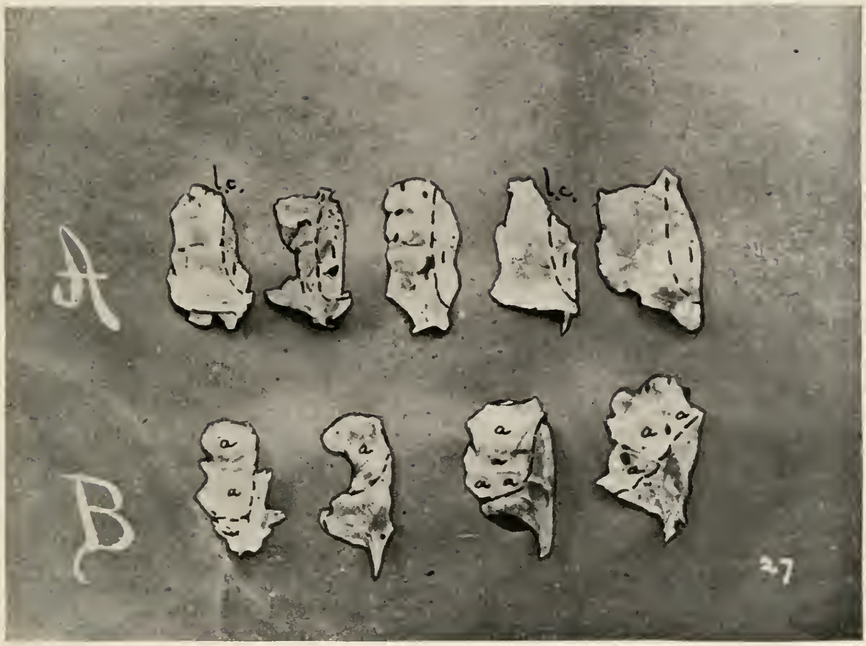
F. Frontal sinus. *n*. Nasal bone. *n.f*. Naso-frontal suture. *B*. Bulla ethmoidalis. *U*. Uncinate process. Arrow passes from turbinate fossa through Ostium frontale to frontal sinus. *l*. Lachrymal bone. *S*. Broad Septum between Uncinate and Bulla.

Plate 26.

BONE. LEFT NASAL CAVITY, EXTERNAL WALL. ANTRUM EXPOSED, LOWER PORTION OF UNCINATE PROCESS BROKEN OFF. INFERIOR TURBINATE BONE REMOVED. MIDDLE TURBINATE BONE REMOVED ALONG DOTTED LINE.

F. Frontal sinus. *c.g.d.* Large Crista Galli diverticulum. Arrow passing between two chambers of the frontal sinus. *B.* Small Bulla ethmoidalis. *U.* Uncinate process. *o.m.* Ostium maxillare. *n.* Nasal bone. *n.p.* Nasal process of frontal bone. *1.* Inferior turbinate crests of superior maxillary and palate bones, for articulation with inferior turbinate bone. *2.* Opening of nasal duct completed by turbinate bone. *3.* Fissura Ethmoidalis Inferior. *A.* Antrum. *l.* Lachrymal bone.

Plate 27.



A Series of Lachrymal Bones.

A. Right lachrymal bones, orbital surface. *B*. Left lachrymal bones, nasal surface. *l.c.* Lachrymal crest. *l*. Lachrymal groove. *a.a.a.* Depressions separated by slightly elevated ridges, completing certain anterior ethmoid cells. Dotted line corresponds to inferior border of uncinate process, the portion of bone below which completes a part of the external wall of nasal fossa. The surface of bone above this line completes ethmoidal cells.

Plate 28.

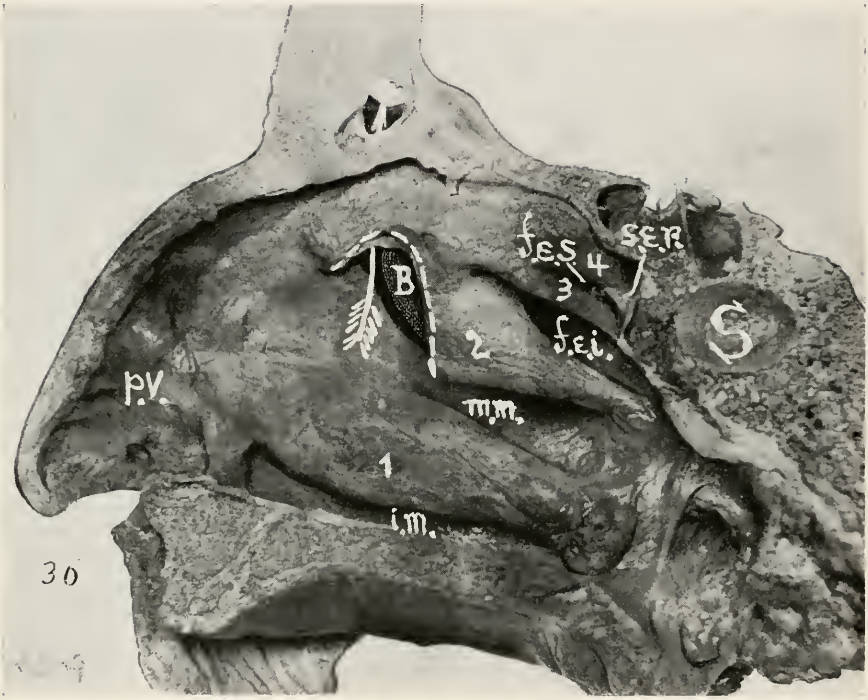
Sagittal Section, Showing Septum Nasi.
F. Frontal sinus. *S.* Sphenoidal sinus. *p.n.* Posterior nares.

Plate 29.

SAGITTAL SECTION, EXTERNAL WALL OF RIGHT NASAL FOSSA.

F. Frontal sinus. *S.* Sphenoidal sinus. *1.* Inferior turbinate bone. *2.* Inferior ethmoidal turbinate bone ("middle turbinate.") 3 and *4.* Middle and superior ethmoidal turbinate bones. *i.m.* Inferior meatus. *m.m.* Middle meatus. *f.e.i.* Fissura ethmoidalis inferior. *f.e.s.* Fissura ethmoidalis superior. *s.e.r.* Spheno-ethmoidal recess. Arrow passes through Ostium sphenoidale. *p.v.* Plica vestibuli. *c.g.* Crista Galli. *e.* Orifice of Eustachian canal. *o.* Operculum. Dotted line corresponds to an incision in middle turbinate bone necessary before removal of its anterior portion, in order to expose satisfactorily the upper extremity of Infundibulum.

Plate 30.



RIGHT NASAL FOSSA, EXTERNAL WALL, PORTION OF MIDDLE TURBINATE REMOVED, AS SHOWN BY DOTTED LINE.

B. Ethmoid Bulla. Arrow passes through Hiatus semi-lunaris into Infundibulum via naso-frontal duct to frontal sinus. *1.* Inferior turbinate bone. *2.* Middle Turbinate bone. *3 and 4.* Superior and middle ethmoidal turbinate bones. *p.v.* Plica vestibuli. *i.m.* Inferior meatus. *m.m.* Middle meatus. *f.e.i.* Fissura ethmoidalis inferior. *f.e.s.* Fissura ethmoidalis superior. *s.e.r.* Spheno-ethmoidal.recess. *S.* Sphenoidal sinus.

Plate 31.

Right Nasal Cavity External Wall, Middle Turbinate Bone Removed Along Dotted Line.

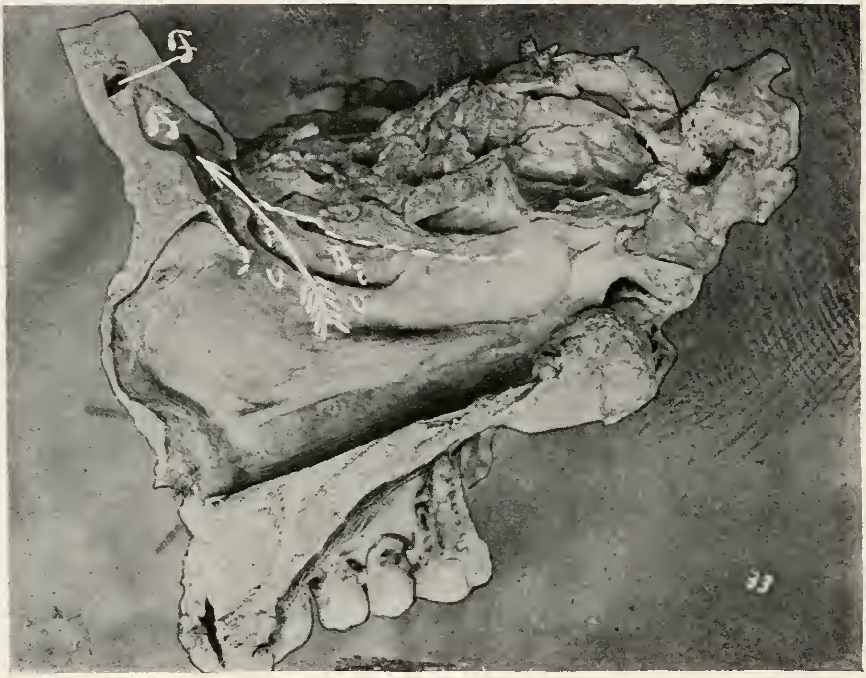
B. Bulla ethmoidalis, its Ostium just above. *U*. Uncinate process. *S*. Septum between Uncinate and Bulla. Arrow passes through turbinate fossa and Ostium frontale into frontal sinus. *h.s.* Hiatus Semi-lunaris leading to infundibulum.

Plate 32.

LEFT NASAL CAVITY, EXTERNAL WALL, MIDDLE TURBINATE BONE REMOVED ALONG DOTTED LINE. ARROW PASSES FROM TURBINATE FOSSA TO FRONTAL SINUS.

B. Bulla ethmoidalis in contact with Uncinate process below. *U*. Uncinate process, Hiatus semi-lunaris between. *s*. Septum between Uncinate and Bulla, separating turbinate fossa from upper end of Infundibulum. *F*. Frontal sinus. *S*. Sphenoidal sinus.

Plate 33.



RIGHT NASAL FOSSA, EXTERNAL WALL, MIDDLE TURBINATE BONE REMOVED, SHOWING INFUNDIBULUM CARRIED NEARLY TO FLOOR OF FRONTAL SINUS, AND CONTINUED AS A SHORT NASO-FRONTAL CANAL, AS SHOWN BY COURSE OF ARROW.

F. Frontal sinus divided by a septum. *U.* Uncinate process. *B.* Small Bulla with a long ostium above it. *i.i.* Marks outer wall of infundibulum with a long ostium above it.

Plate 34.

RIGHT NASAL FOSSA, MIDDLE TURBINATE REMOVED.

t. Turbinate fossa leading to frontal sinus. Arrow. *B*. Small ethmoid Bulla. *U*. Uncinate process. *f.e.i.* Fissura ethmoidalis inferior, in which may be seen ostia of posterior ethmoidal cells. *S*. Sphenoidal sinus opening into recessus Spheno-ethmoidalis. *i*. Arrow disappearing through Hiatus frontalis into Infundibulum. *a.o.m*. Accessory Ostium maxillare.

Plate 35.

LEFT NASAL FOSSA, EXTERNAL WALL, MIDDLE TURBINATE REMOVED, SHOWING ABSENCE OF SEPTUM BETWEEN BULLA ETHMOIDALIS AND UNCINATE PROCESS, WHEREBY THE TURBINATE FOSSA AND UPPER END OF INFUNDIBULUM COINCIDE.

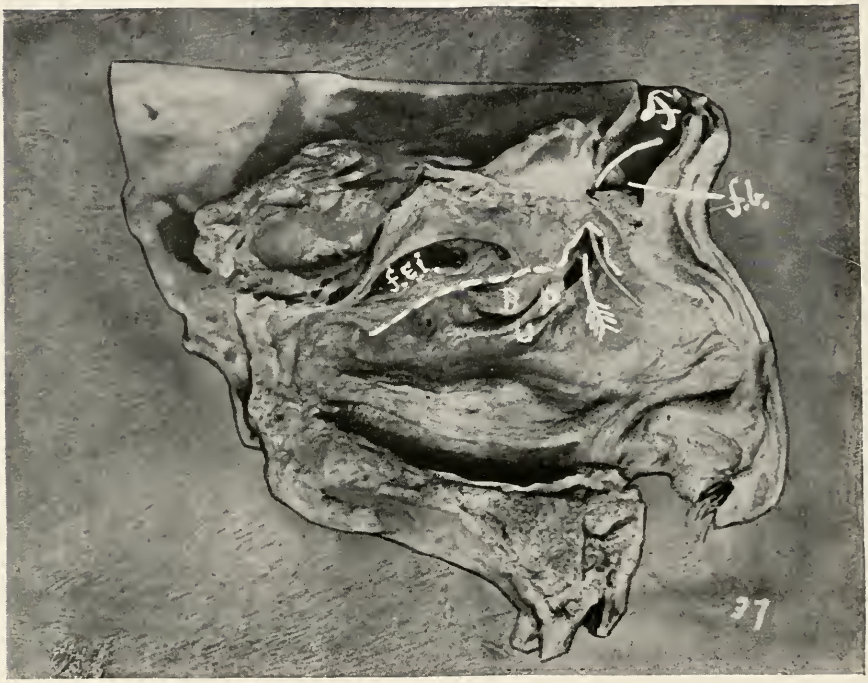
F. Frontal sinus. *B.* Bulla ethmoidalis. *U.* Uncinate process. Hiatus semilunaris between these two, in which can be seen a small probe, (1) passing from the *Antrum to the Frontal Sinus.* Large probe, (2) passing from sinus through a second ostium frontale appearing just under the middle turbinate bone. A small septum can be seen between these probes, which separates ostia of anterior ethmoidal cells. Accessory ostium maxillare of large size, to be seen just above inferior turbinate bone. See Plate 36.

Plate 36.

SAME SPECIMEN ENLARGED, MORE OF THE TURBINATE BONE REMOVED, SHOWING FREE PASSAGE TO FRONTAL SINUS. ARROW LEADS TO OSTIUM MAXILLARE.

a.o.m. Accessory ostium maxillare.

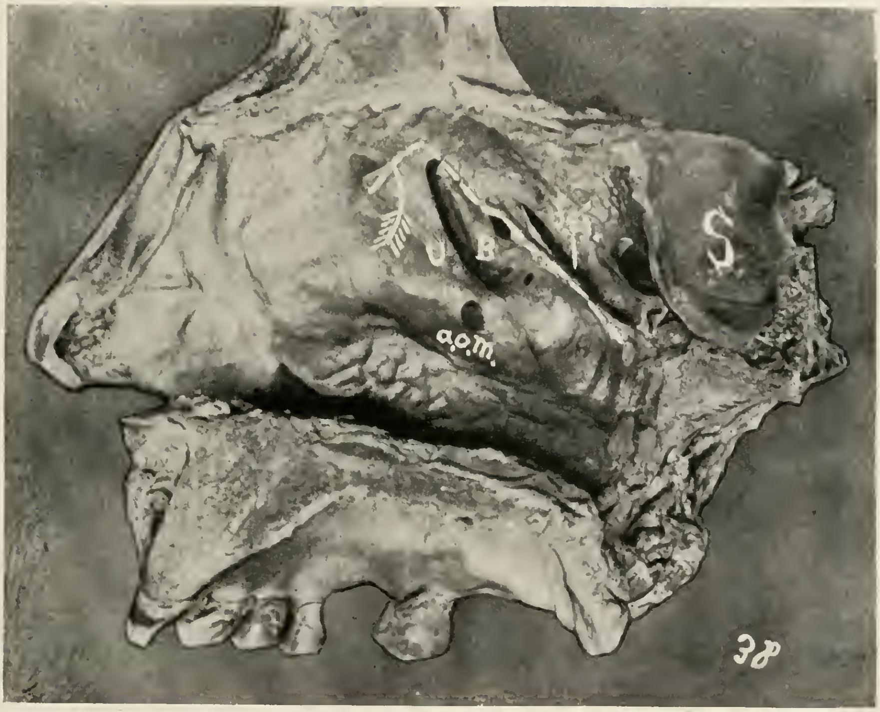
Plate 37.



Left Nasal Fossa, External Wall, Turbinate Bone Removed. Probe from Turbinate Fossa to Frontal Sinus. Arrow is lost in Infundibulum under Septum between Bulla Ethmoidalis and Uncinate Process. Lower Portion of Hiatus Semi-Lunaris Obstructed by a small Polyp (*p*) which hangs from the Ethmoid Bulla (*B*).

f.e.i. Fissura ethmoidalis inferior. *F.* Frontal sinus. *f.b.* Frontal Bulla.

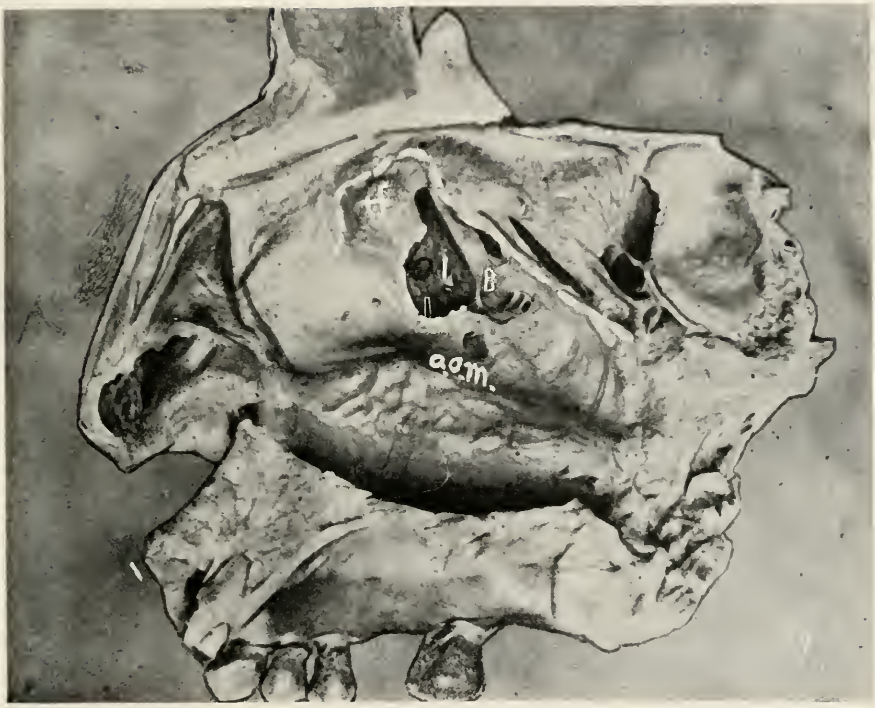
Plate 38.



RIGHT NASAL FOSSA, EXTERNAL WALL, MIDDLE TURBINATE REMOVED WITH ARROW LEADING TO TURBINATE FOSSA, WHICH ENDS BLINDLY UNDER THE SUPERIOR ANGLE OF THE TURBINATE.

B. Bulla ethmoidalis, with its Ostium. *U.* Uncinate process. Well marked Hiatus Semi-lunaris between these two structures leading to Infundibulum, into which opens the naso-frontal canal. *a.o.m.* Accessory Ostium maxillare. *f.e.i.* Fissura ethmoidalis inferior. *S.* Sphenoidal Sinus. See Plate 39.

Plate 39.



Same Specimen, more of the Turbinate Bone Removed, Exposing the Turbinate Fossa.

t.f. Turbinate fossa. Portion of Uncinate process removed showing depth of Infundibulum at the lowest point of which is a small probe in the Ostium maxillare. On the external wall of the Infundibulum are small cell-like cavities. *a.o.m.* Accessory Ostium maxillare. *B.* Bulla ethmoidalis, with its ostium just above. *i.* External wall of Infundibulum.

Plate 40.

Left Nasal Fossa, External Wall, Middle Turbinate Removed. Uncinate Process Incised, and its Upper Portion Reflected Forward and Retained in Position by a Probe Passing Down from the Frontal Sinus into the Infundibulum. A Short Probe Shows the Location of the Ostium Maxillare.

a.o.m. Accessory Ostium maxillare. *U.* Reflected portion of Uncinate process. *B.* Bulla ethmoidalis, with a long ostium above. *f.e.i.* Fissura ethmoidalis inferior. *S.* Sphenoidal sinus. *i.t.* Inferior turbinate. *i.i.i.* Infundibulum. *F.* Frontal sinus.

Plate 41.

LEFT NASAL FOSSA, EXTERNAL WALL, MIDDLE TURBINATE REMOVED, UNCINATE PROCESS DIVIDED AND UPPER PORTION REFLECTED FORWARD AND INWARD. PROBE PASSED FROM FRONTAL SINUS TO ANTRUM THROUGH NASO-FRONTAL CANAL AND INFUNDIBULUM SHOWING ITS DEPTH AND THE TENDENCY OF FLUIDS TO GRAVITATE INTO THE ANTRUM.

B. Bulla ethmoidalis with its Ostium just above. *u.u.* On portions of uncinate process. *a.o.m.* Accessory Ostium maxillare. *f.e.i.* Fissura ethmoidalis inferior. *S.* Sphenoidal sinus. *F.* Frontal sinus broken away. *s.* Septum between uncinate process and Bulla ethmoidalis separating a blind turbinate fossa from the upper extremity of the Infundibulum.

Plate 42.

RIGHT NASAL FOSSA, EXTERNAL WALL; MIDDLE TURBINATE AND PART OF FLOOR OF FRONTAL SINUS REMOVED, SO AS TO SHOW A DIRECT COMMUNICATION BETWEEN THE INFUNDIBULUM AND SINUS.

B. Bulla ethmoidalis, very large and overhangs the Uncinate process, so as to obscure the Hiatus Semi-lunaris, its long ostium continued well toward the frontal sinus; its mucous membrane is considerably hypertrophied. *U*. Processus Uncinatus. *i.i.i.* Infundibulum. *f.e.i.* Fissura ethmoidalis inferior, above which hangs a small polyp. *F*. Frontal Sinus. See Plate 44.

Plate 43.

Left Nasal Fossa, External Wall, Middle and Inferior Turbinates Removed along Dotted Lines. Arrow through Turbinate Fossa to Frontal Sinus.

B. Bulla ethmoidalis, rather small with large ostium above. *h.s.* Hiatus Semi-lunaris narrowed below by the approximation of the Bulla ethmoidalis and processus Uncinatus (*U*). *f.e.i.* Fissura ethmoidalis inferior. *i.m.* Inferior meatus.

Plate 44.

SAME SPECIMEN (REDUCED IN SIZE) AS PLATE 42, LESS OF MIDDLE TURBINATE REMOVED; FIGURES CORRESPOND TO THOSE IN PREVIOUS PLATE. ARROW PASSES TO FRONTAL SINUS THROUGH HIATUS SEMI-LUNARIS.

Plate 45.

LEFT NASAL FOSSA, EXTERNAL WALL, MIDDLE TURBINATE BONE PARTIALLY SEVERED AND HANGING IN FRONT OF INFERIOR TURBINATE.
ARROW PASSES THROUGH TURBINATE FOSSA TO FRONTAL SINUS.

F. Frontal Sinus. *S.* Broad Septum, from Uncinate process to Bulla ethmoidalis, forming the inner wall of the turbinate fossa. *c.c.c.* Cells in middle turbinate bone. *p.* Fine probe in small Hiatus Semi-lunaris. *B.* Bulla ethmoidalis, very small. *U.* Processus Uncinatus, very small.

Plate 46.

Left Nasal Fossa, External Wall, Specimen Reduced in Size, Middle Turbinate Removed.

B. Ethmoid Bulla small, but markedly convex forward and downward so as to over-lap the Uncinate process. *U*. Uncinate process. Arrow is lost in a blind Infundibulum. *p*. Probe passing through turbinate fossa to frontal sinus. *f.e.i.* Fissura ethmoidalis inferior.

Plate 47.

LEFT NASAL FOSSA, EXTERNAL WALL, MIDDLE TURBINATE REMOVED.

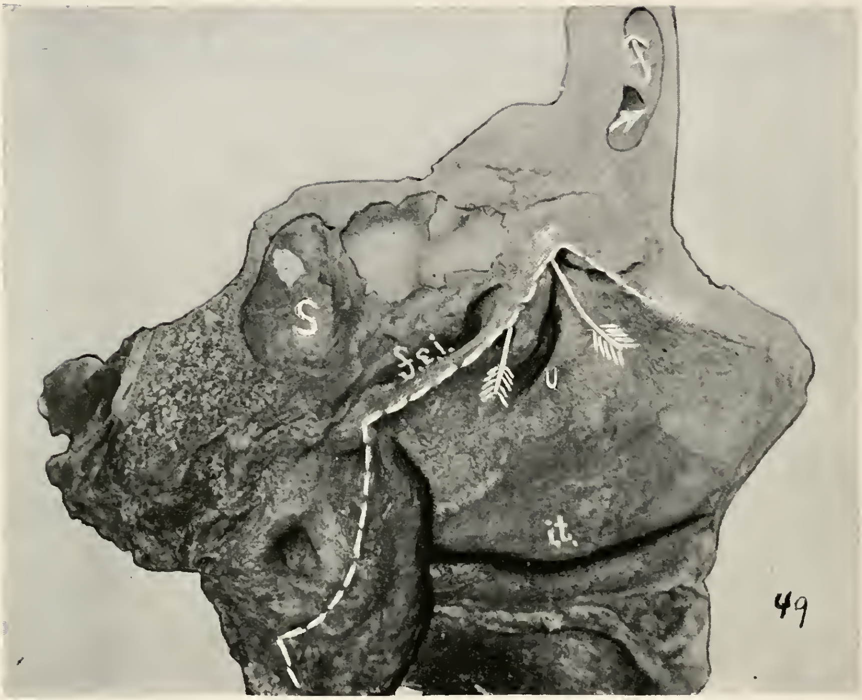
Arrow passes through turbinate fossa to frontal sinus. *B*. Cavity of Bulla ethmoidalis opened on section. *U*. Uncinate process. *h.s.* Broad Hiatus Semilunaris. *a.o.m.* Accessory Ostium maxillare. *f.e.i.* Fissura ethmoidalis inferior. *S*. Sphenoidal sinus.

Plate 48.

Internal Wall of Left Orbital Fossa, Showing Extensive Dehiscence of Os Planum, which Communicates with the Cells of the Ethmoid Bulla. Arrow Passing Through Dehiscence to the Cells of the Bulla Ethmoidalis.

n.d. nasal duct. *A.* Antrum.

Plate 49.



Nasal Aspect of Same Specimen, Middle Turbinate Removed and Left Hanging.

B. Bulla ethmoidalis. *U*. Processus Uncinatus. Arrow passes through the ostium of the Bulla ethmoidalis and the dehiscence of the Os Planum, into the orbital fossa. The upper arrow passes through the turbinate fossa and ostium frontale to the frontal sinus. *F*. Frontal sinus. *S*. Sphenoidal sinus. *f.e.i.* Fissura ethmoidalis inferior. *i.t.* Inferior turbinate.

Plate 50.

INTERNAL WALL OF LEFT ORBITAL FOSSA, TO SHOW A SMALL DEHISCENCE BETWEEN THE LACHRYMAL BONE AND OS PLANUM.

o.p. Os Planum. *l.* Os lachrymale. *s.m.* Orbital surface of superior maxilla. *F.* Frontal sinus. *a.* Anterior wall. *p.* Posterior wall. *i.* Inferior wall. *e.* Anterior ethmoidal foramen. *D.* Dehiscence. *A.* Antrum.

Plate 51.

Sagittal Section to Left of Medium Line, Exposing the Frontal Sinus and Ethmoidal Cells.

F. Frontal sinus. *a.* Anterior wall. *p.* Posterior Wall. *f.b.* Frontal Bulla protruding into frontal sinus; its cell large. *U.* Uncinate process to which are attached numerous polypi so as to obstruct the Hiatus semi-lunaris. The anterior portion of the uncinate process has been partly removed so as to expose a large cell situated between this process and the lachrymal bone. Its ostium is marked by an arrow directed toward the Infundibulum. This cell is of very constant occurrence. *B.* In cell corresponding to Bulla ethmoidalis. Dotted lines indicate points of removal of middle turbinate. *S.* Sphenoidal sinus. *c.* An Anterior ethmoidal cell. *i.t.* Inferior turbinate. *p.v.* Plica vestibuli. *a.o.m.* Accessory Ostium maxillare. *d.* Posterior ethmoid cells. *i.m.* Inferior meatus. *m.m.* Middle meatus. The long arrow passes through the Hiatus Semi-lunaris into the Infundibulum, which is converted into a canal by polypi, thence through the exposed naso-frontal canal into the frontal sinus.

Plate 52.

Sagittal Section to Right of Median Line, Lower Portion of Uncinate Process Removed, and Large Opening made into Antrum, Middle Turbinate Removed.

F. Frontal sinus. *A.* Antrum. *B.* Bulla ethmoidalis. *i.* Large cell just external to upper end of Infundibulum which has been removed. *f.e.i.* Fissura ethmoidalis inferior. *U.* Uncinate process.

Plate 53.

Sagittal Section Through Eye-ball, internal half, Showing the Triangular Shape of the Frontal Sinus.

F. Frontal sinus. *a.* Anterior wall. *i.* Inferior wall. *p.* Posterior wall. *f.b.* Large frontal bulla. *A.* Antrum. *a.o.m.* Accessory Ostium maxillare. *E.* Eyeball. *m.c.f.* Middle cranial fossa. See Plate 54.

Plate 54.

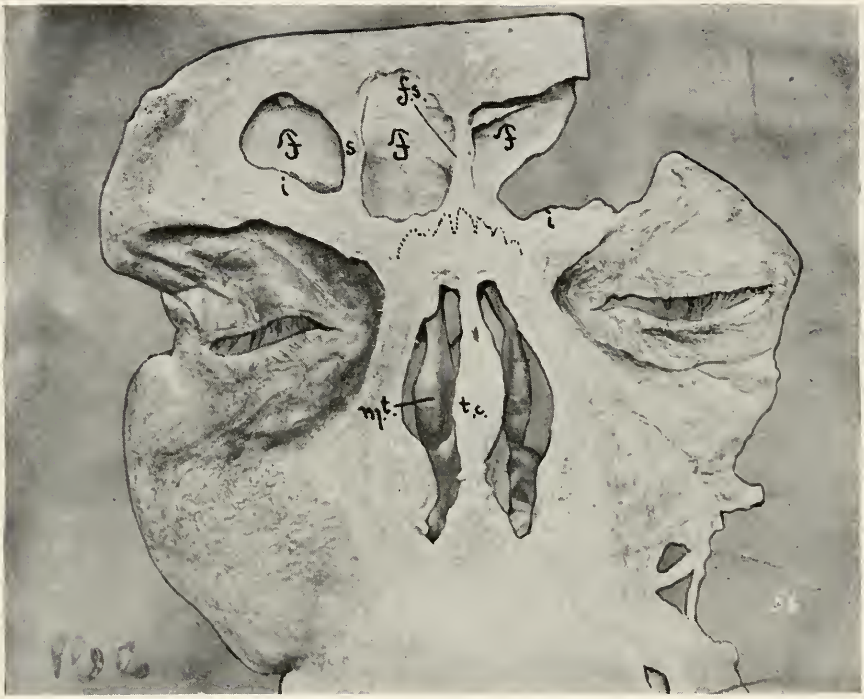
Same Specimen, External Half, Letters Correspond. (See Plate 53.)

Plate 55.

Coronal Section Looking into a Large Frontal Sinus, Containing Numerous Septa but no Inter-Frontal Septum. Both Sinuses Form One Cavity. Arrow Marks the Presence of a Single Ostium Frontale which Opens into the Right Turbinate Fossa. No Ostium Frontale on the Left of the Median Line.

s.s.s. Various incomplete septa of the common frontal sinus. *f.b.* Frontal bulla on left side which opens into the left turbinate fossa.

Plate 56.



CORONAL SECTION THROUGH FRONTAL SINUS.

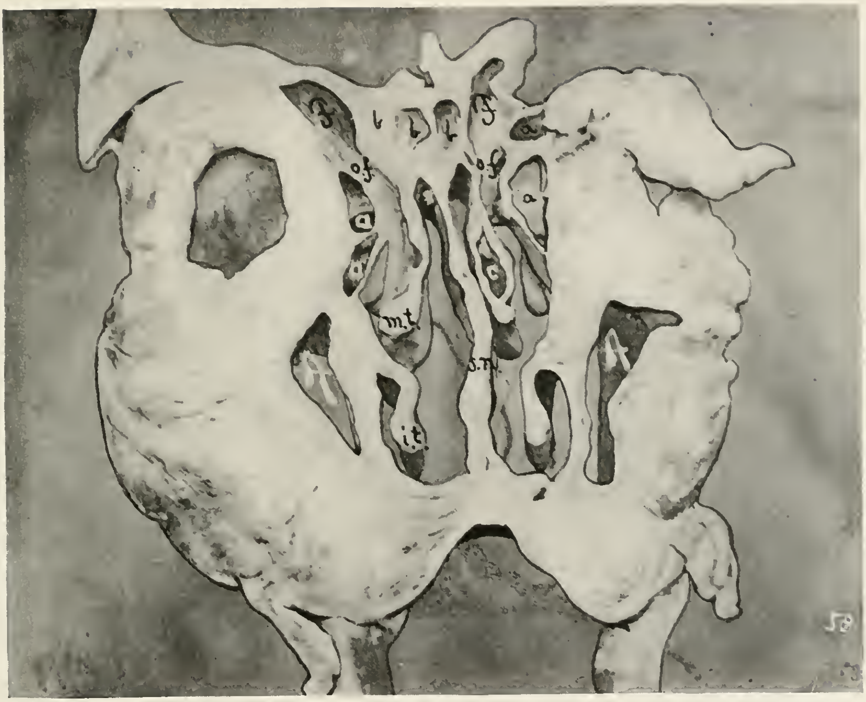
F. Frontal sinus, posterior wall. *f.s.* Septum between frontal sinuses. *s.* Thick Septum in the right frontal sinus, dotted line marks the suture between the frontal bone on the one hand, and the nasal and superior maxillary bones on the other hand. *m.t.* Middle turbinate. *i.* Inferior surface of frontal sinus (orbital portion). *t.c.* Triangular cartilage of nasal septum.

Plate 57.

Coronal Section Through Posterior Portion of Frontal Sinus Passing Through Nasal Canal.

F.F. Frontal sinuses each divided by a septum (*s*). *i.s.* Inter-frontal septum. *f.c.* Frontal crest. *m.t.* Left middle turbinate containing a cell. Arrow passing through turbinate fossa to frontal sinus. *n.d.* Nasal ducts with probes. *A.* Antrum. *i.t.* Inferior turbinate. *i.m.* Inferior meatus. *m.m.* middle meatus. *s.m.* Superior meatus. *a.a.a.* Anterior Ethmoid cells opposite lachrymal bone. *s.n.* Septum nasi.

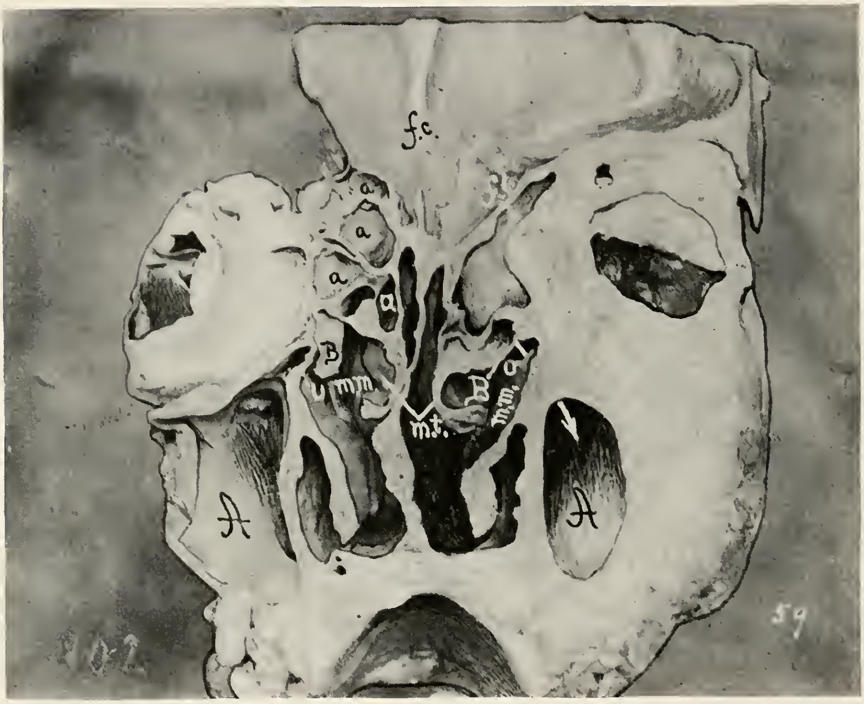
Plate 58.



CORONAL SECTION THROUGH OSTIUM FRONTALE OF BOTH SINUSES, POSTERIOR HALF.

F. Frontal sinus. *o.f.* Ostium Frontale (posterior half) at apex of turbinate fossa. *c.* Cell in left middle turbinate. *a.a.a.* Anterior ethmoid cells, opposite lachrymal bone. *b.b.* Anterior ethmoid cells internal to Ostium frontale. *A.* Antrum. *i.t.* Inferior turbinate. *m.t.* Middle turbinate. *s.n.* Septum nasi.

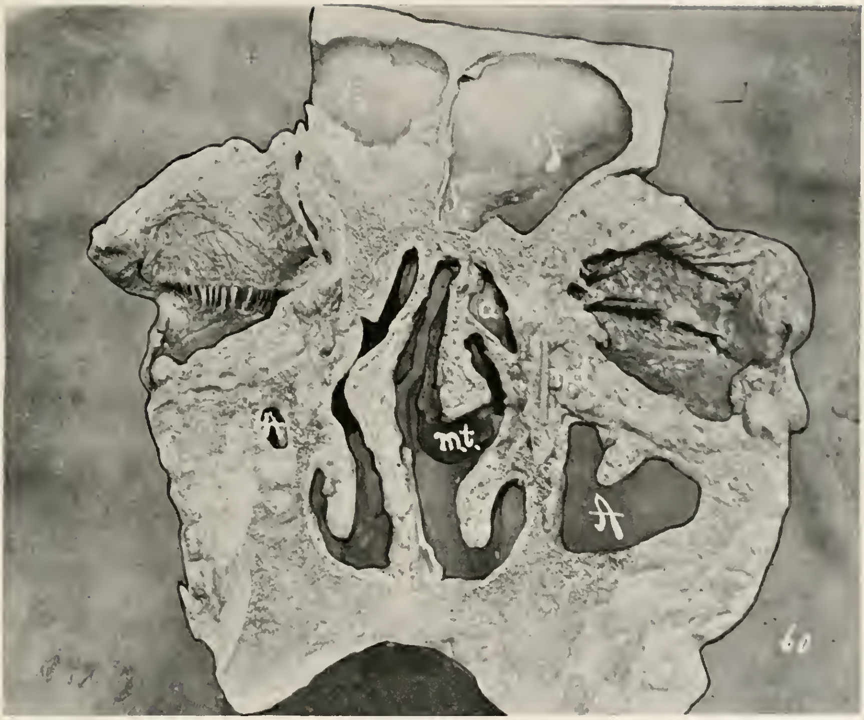
Plate 59.



CORONAL SECTION THROUGH THE LEFT OSTIUM MAXILLARE AND BEHIND THE RIGHT OSTIUM MAXILLARE, AS SHOWN BY ARROW PASSING FROM INFUNDIDULUM TO ANTRUM.

A. Antrum. *U*. Uncinate process. *f.c.* Frontal crest. *f.b.* Frontal Bulla. *m.t.* Middle turbinate. *a.a.a.* Anterior ethmoid cells. *B*. Bulla ethmoidalis on section. *m.m.* Middle meatus.

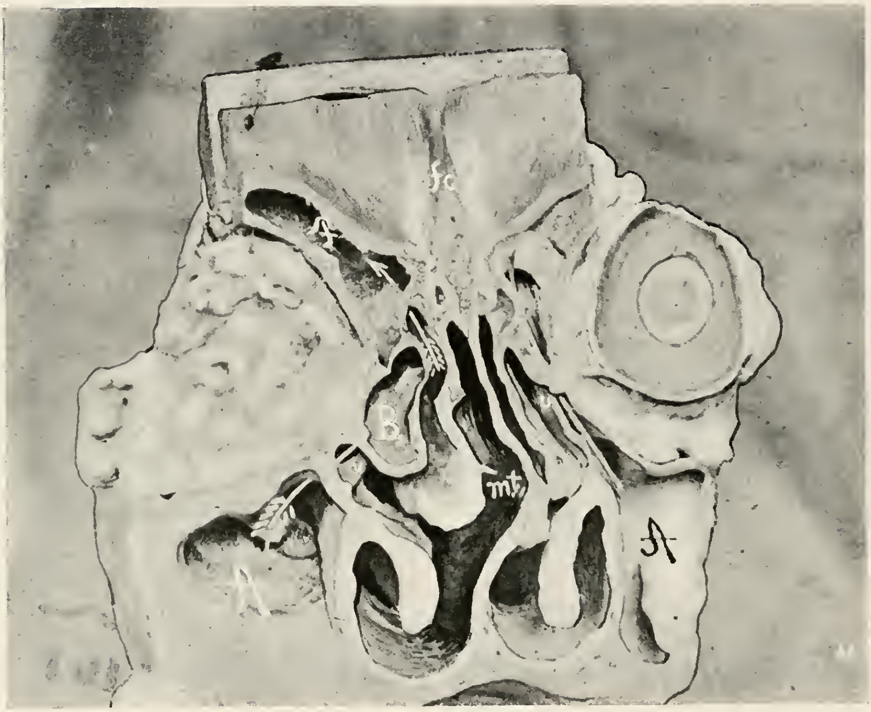
Plate 60.



CORONAL SECTION THROUGH FRONTAL SINUS PASSING THROUGH NASAL DUCTS, AS SHOWN BY PROBE IN LEFT DUCT. (*n.d.*)

F. Frontal sinus, posterior wall. *f.s.* Frontal septum, becoming thicker toward the floor of the right sinus. *m.t.* Middle turbinate with very broad lower border, in consequence of a deep turbinate sinus. *A.* Antrum. *a.* Anterior ethmoid cell.

Plate 61.



Coronal Section, Anterior Portion, Passing Through Right Ostium Maxillare, but Posterior to that on the Left Side, as shown by Arrow Passing Into Infundibulum. Probe on Right Side, in Infundibulum. An Arrow passes from Left Turbinate Fossa to Frontal Sinus.

F. Frontal Sinus, showing superior and inferior walls. *B.* Bulla ethmoidalis (left) on section. *m.t.* Middle turbinate. *U.* Processus Uncinatus. *A.* Antrum. *f.c.* Frontal crest.

Plate 62.

Coronal Section, Posterior Portion, just Anterior to Bulla Ethmoidalis on Right Side, but on Left Side Bulla is Seen on Section.

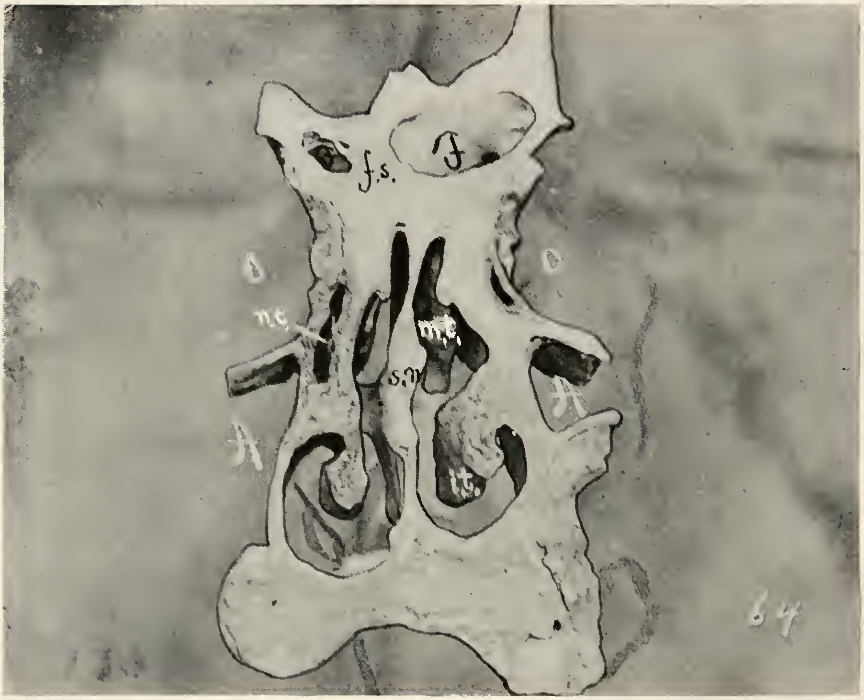
F. Frontal sinus, showing posterior and inferior walls. *B.* Bulla ethmoidalis. *a.a.* Anterior ethmoid cells just above Bulla. *m.t.* Middle turbinate much curled, forming a deep sinus turbinalis (*s.t.*) *i.m.* Inferior meatus. *m.m.* Middle meatus. *s.m.* Superior meatus. *s.n.* Septum nasi with prominent spur. *A.* Antrum. *c.g.* Crista Galli.

Plate 63.

Coronal Section Passing through Frontal Sinuses, Right Nasal Duct (arrow) and both Antra. Anterior Portion.

A. Antrum. *F.* Frontal sinus. *i.t.* Anterior extremity of inferior turbinate. *m.t.* Anterior extremity of middle turbinate. *s.n.* Septum nasi. *f.s.* Thick septum between frontal sinuses. *f.c.* Frontal crest. A wire is seen passing across a thick portion of bone just anterior to the Hiatus frontalis, at the articulation of the frontal bone with the nasal bone and the nasal process of the superior maxilla.

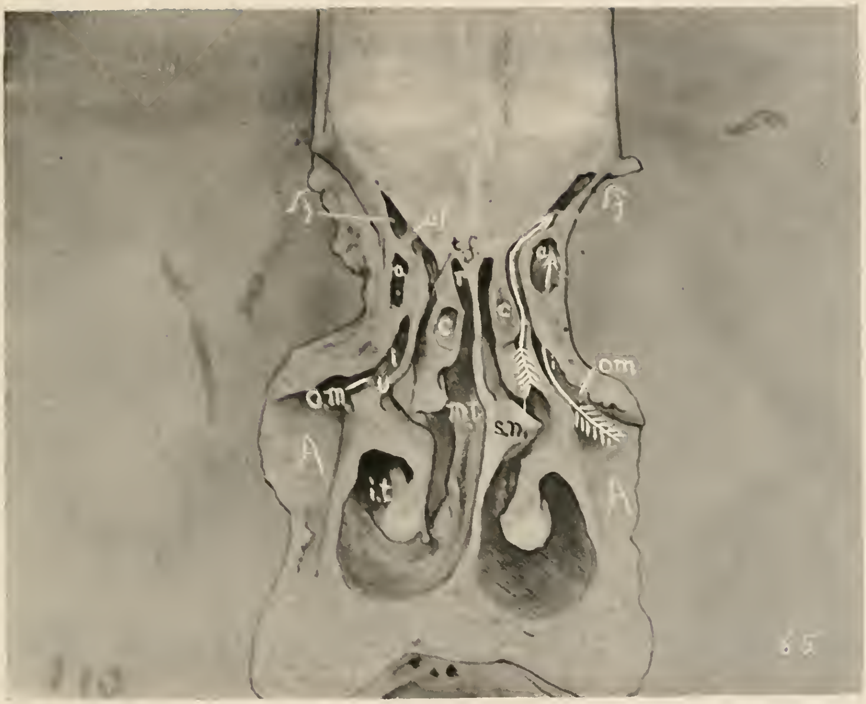
Plate 64.



CORONAL SECTION THROUGH THE FRONTAL SINUS AND NASAL DUCTS.

F. Frontal sinus. *f.s.* Frontal septum. *n.c.* Nasal canal. *A.* Antrum. *O.* Orbital fossa. *s.n.* Septum nasi. *i.t.* inferior turbinate. *m.t.* Middle turbinate.

Plate 65.



Coronal Section, Anterior Portion Passing Through Both Ostia Maxillaria and the Posterior Angles of the Frontal Sinuses.

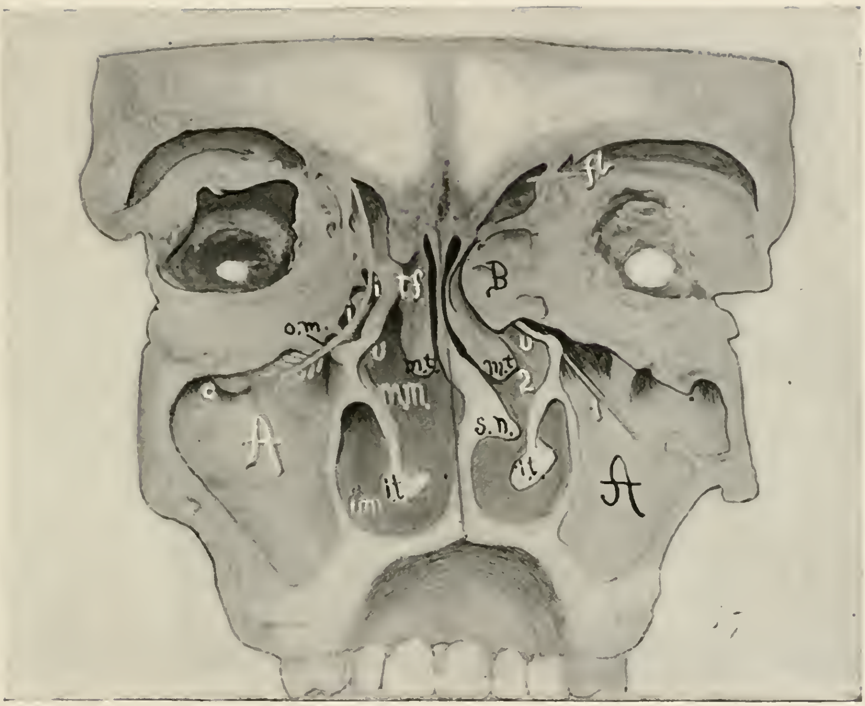
F. Frontal sinus. *A.* Antrum. *o.m.* Anterior portion of Ostium maxillare. *U.* Processus Uncinatus. On right side arrow passes through Ostium maxillare into Infundibulum to appear in a cell opposite lachrymal bone, and a second arrow passes through the turbinate fossa to the frontal sinus. *a.a.* Anterior ethmoidal cells opposite lachrymal bone. *i.* Infundibulum. *o.f.* Anterior portion of Ostium frontale. *t.f.* Turbinate fossa. *i.t.* Inferior turbinate. *m.t.* Middle turbinate. *c.* Cells in middle turbinate bone. *s.n.* Septum nasi with spur. *r.* Roof of nasal fossa.

Plate 66.

CORONAL SECTION THROUGH OSTIUM MAXILLARE, POSTERIOR PORTION JUST INCLUDING THE POSTERIOR ANGLE OF FRONTAL SINUS.

F. Frontal sinus. *U.* Uncinate process. *B.* Bulla ethmoidalis showing two cells. *o.m.* Posterior portion of Ostium maxillare. *A.* Space occupied by Antrum. *O.* Orbital fossa. *a.a.a.* Anterior ethmoidal cells. *m.t.* Middle turbinate.

Plate 67.



CORONAL SECTION THROUGH OSTIUM MAXILLARE, ANTERIOR PORTION. ON LEFT SIDE BULLA ETHMOIDALIS REMOVED, SHOWING ARROW PASSING THROUGH OSTIUM MAXILLARE AND INFUNDIBULUM TO A LARGE FRONTAL BULLA.

B. Large Bulla ethmoidalis on section. *1.* Probe passing from Antrum to a frontal bulla seen on section. *f.b.* Frontal bulla. *2.* Probe passing through turbinate fossa to the frontal sinus. *U.* Processus Uncinatus. *A.* Antrum. *i.m.* Inferior meatus. *m.m.* Middle meatus *t.f.* Turbinate fossa. *i.t.* Inferior turbinate. *m.t.* Middle turbinate. *c.* Cyst in Mucous membrane of Antrum. *o.m.* Anterior portion of Ostium maxillare. *i.* Infundibulum. *s.n.* Septum nasi with large spur. See Plate 68.

Plate 68.

Same Specimen, Posterior Portion.

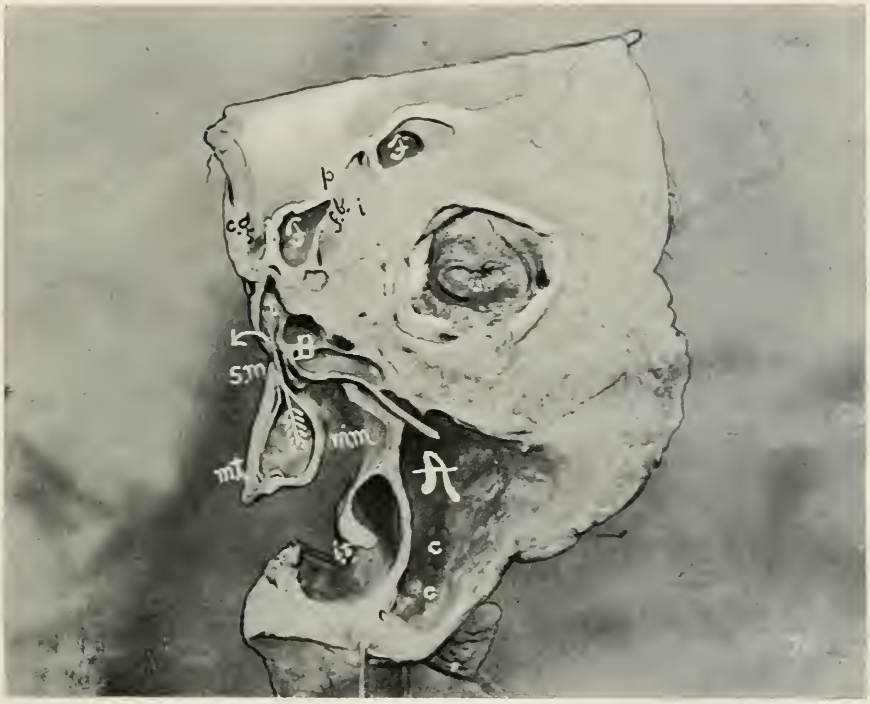
A. Antrum. *o.m.* Ostium maxillare, posterior edge. *c*. Cysts in mucous membrane of Antrum. *U*. Processus Uncinatus. *i.t.* Inferior turbinate. *m.t.* Middle turbinate. *B*. Bulla ethmoidalis on section composed of several cells. *F*. Posterior angles of frontal sinus. *t*. Cell in right turbinate bone. *s.n.* Septum nasi with large spur.

Plate 69.

CORONAL SECTION, POSTERIOR TO OSTIUM MAXILLARE WHICH CONTAINS A PROBE.

A. Antrum. *B*. Bulla ethmoidalis very broad and overhanging. *i.t.* Inferior turbinate. *m.t.* Middle turbinate. *i.m.* Inferior meatus. *m.m.* Middle meatus. *U*. Processus Uncinatus. *a.a.* Anterior ethmoidal cells. *c.g.* Crista galli. *i.* Internal wall of lateral mass.

Plate 70.



CORONAL SECTION, ANTERIOR PORTION, THROUGH OSTIUM MAXILLARE AND POSTERIOR PORTION OF A LARGE FRONTAL SINUS; SEPTUM OF THE NOSE REMOVED.

A. Antrum with small cysts (*c*). Probe passes from Antrum through Infundibulum to frontal sinus. The Infundibulum is converted into a canal by the approximation of the Uncinate process and ethmoid bulla. *B.* Ethmoid bulla containing two cells. *F.F.* Frontal sinus (*p*) posterior wall (*i*) inferior wall. *i.t.* Inferior turbinate. *m.t.* Middle turbinate containing a very large cell which opens into the superior meatus, as shown by arrow. *f.b.* Anterior wall of frontal bulla. *m.m.* Middle meatus. *s.m.* Superior meatus. *c.g.* Crista galli. *t.* Turbinate fossa. See Plate 71.

Plate 71.

POSTERIOR PORTION OF SPECIMEN, FIGURED IN PLATE 70.

F. Frontal sinus. *f.b.* Frontal Bulla on section. *A.* Antrum. *o.m.* Ostium maxillare posterior portion. *i.t.* Inferior turbinate. *m.t.* Middle turbinate containing posterior half of cell seen in Plate 70. *U.* Uncinate process. *B.* Bulla ethmoidalis in contact with Uncinate process. *i.* Infundibulum.

Plate 72.

HORIZONTAL SECTION AT THE LEVEL OF THE LAMINA CRIBROSA SHOWING A CONSIDERABLE PORTION OF THE FLOOR OF THE LEFT FRONTAL SINUS.

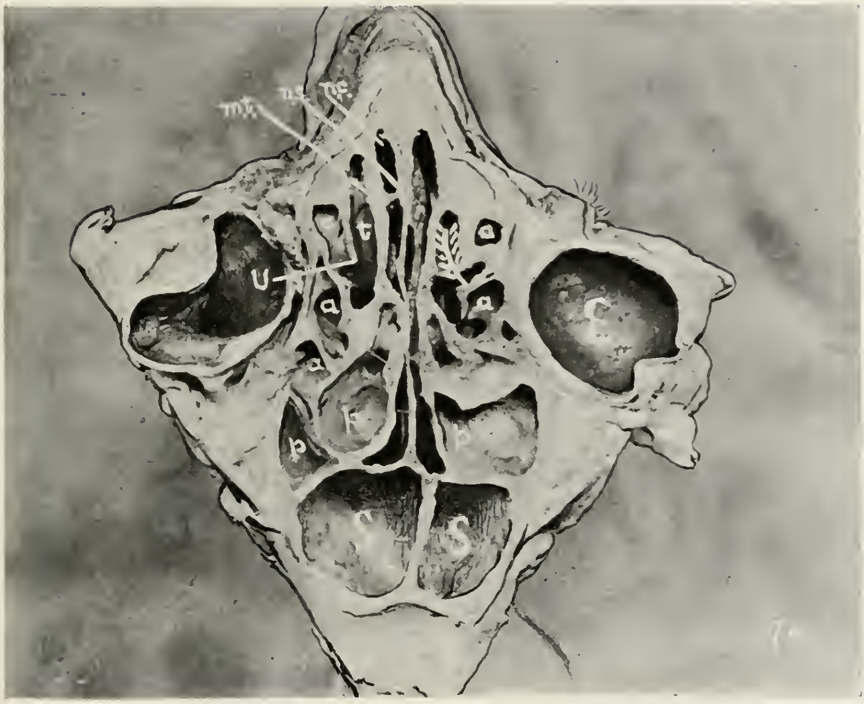
F. Frontal sinus. *l.c.* Lamina cribrosa, a small portion on either side of the Crista galli (*c.g*). *f.s.* Septum between the frontal sinuses. *p.* Posterior angle of left frontal sinus. *a.a.a.* Some anterior ethmoid cells. *S.* Sphenoidal sinus, septum to right of median line. *p.e.* Posterior ethmoid cell.

Plate 73.

Horizontal Section just above the Ostium Maxillare Looking Downward.

n.s. Nasal septum. *A.* Apex of Antrum. *o.m.* Ostium Maxillare. *U.* Processus Uncinatus. *m.t.* Portion of middle turbinate. *S.* Left sphenoidal sinus. Arrow passes down right Infundibulum through Ostium maxillare to Antrum.

Plate 74.



HORIZONTAL SECTION JUST BELOW THE LAMINA CRIBROSA LOOKING DOWNWARD, SHOWING NUMEROUS ANTERIOR AND POSTERIOR ETHMOIDAL CELLS.

a.a.a. Anterior ethmoidal cells. *p.p.p.* Posterior ethmoidal cells. *U.* Upper extremity of Uncinate process. *m.t.* Anterior extremity of middle turbinate meeting the nasal process of the superior maxilla in front. *t.* Turbinate fossa. *S.* Sphenoidal sinus. Arrow passing down Infundibulum to Antrum. *n.s.* Nasal septum. *E.* Eyeball. *n.c.* Nasal cavity.

Plate 75.

Horizontal Section just Above Ostium Maxillare Looking Downward Through The Middle Turbinate Showing its upper Horizontal Portion. Arrow Passes Down Left-Infundibulum Through Ostium Maxillare to Antrum.

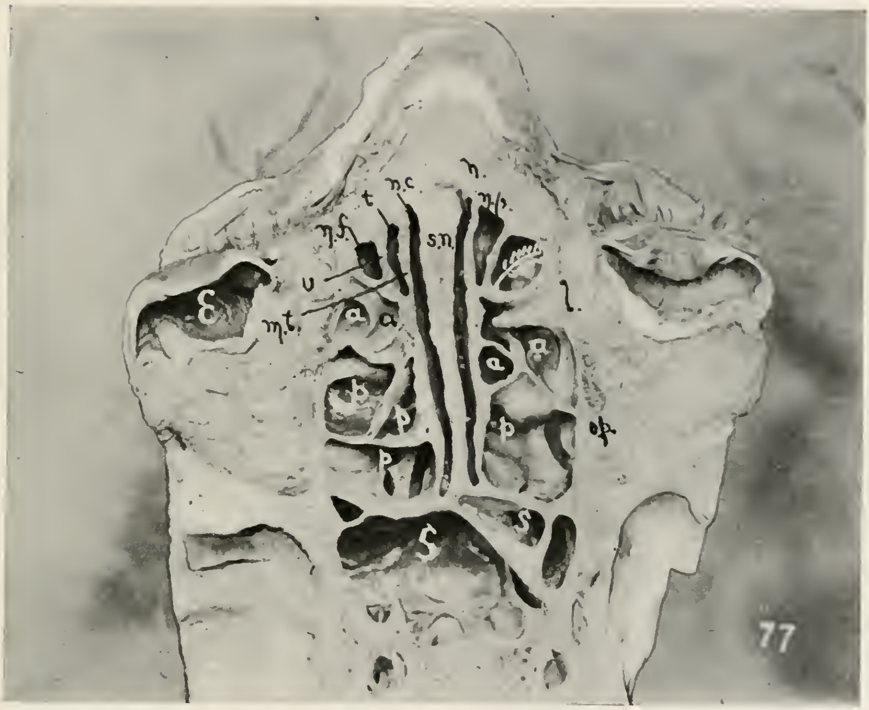
o.m. Ostium Maxillare. *U.* Uncinate process. *n.d.* Nasal duct. *n.c.* Nasal cavity. *m.t.* Middle turbinate, showing its horizontal portion. *s.t.* Superior turbinate, posterior extremity. *O.* Orbital surface of Antrum. *S.* Sphenoidal sinus. *s.* External concave surface of middle turbinate showing sinus turbinalis. *B.* Bulla ethmoidalis (lower portion). *p.* Posterior ethmoid cell.

Plate 76.

HORIZONTAL SECTION JUST ABOVE THE LAMINA CRIBROSA SHOWING FLOOR OF FRONTAL SINUS.

F. Frontal sinus. Arrow passing through right Ostium frontale. *f.b.* Frontal Bulla. *i.* Inferior wall of frontal sinus, corresponding to inferior lamina of frontal bone. (Orbital portion). *p.* Posterior wall of frontal sinus corresponding to the superior lamina of the orbital portion of the frontal bone. *c.g.* Crista galli. *f.s.* Septum between the frontal sinuses. *l.c.* Lamina cribrosa. *C.* Anterior cranial fossa.

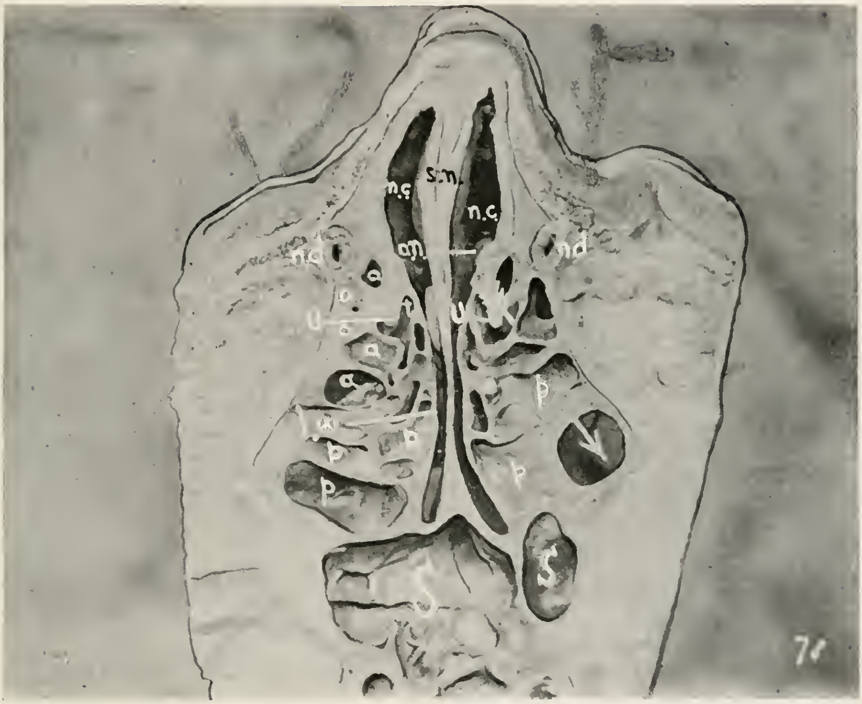
Plate 77.



HORIZONTAL SECTION JUST BELOW LAMINA CRIBROSA, LOOKING DOWNWARD, SHOWING NUMEROUS ANTERIOR AND POSTERIOR ETHMOIDAL CELLS.

s.n. Septum nasi. *a.a.a.* Some anterior ethmoidal cells. *p.p.p.* Some posterior ethmoidal cells. *n.f.* Naso-frontal canal. *t.* Apex of turbinate fossa. *n.c.* Nasal cavity. *S.* Sphenoidal sinus with septum far to the right of median line. *U.* Upper extremity of uncinate process. *m.t.* Anterior upper extremity of middle turbinate. *E.* Eyeball. *n.* Nasal bone. *n.p.* Nasal process of superior maxilla. *l.* Lachrymal bone. *o.p.* Os Planum. Arrow passes down into right naso-frontal canal from right frontal sinus.

Plate 78.



HORIZONTAL SECTION OF SAME SPECIMEN AT A LOWER LEVEL THAN PLATE 77, LOOKING DOWNWARD.

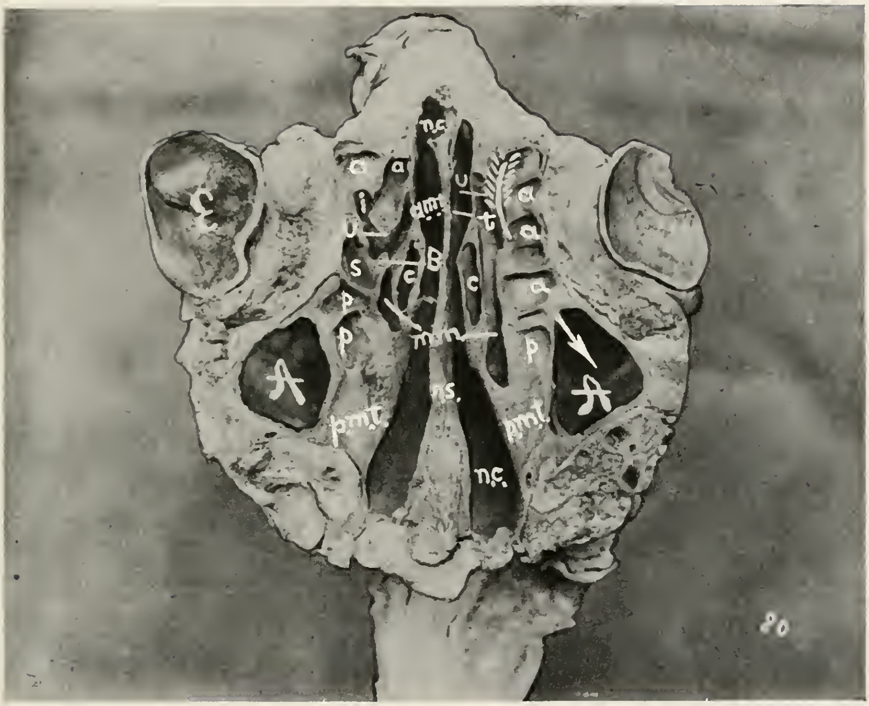
s.n. Nasal septum. *n.c.* Nasal cavity. *n.d.* Nasal duct. *U.* Processus Uncinatus. *i.* Infundibulum on right side through which the arrow seen in Plate 77, continues to the antrum, which has been exposed on the right side only. *a.a.a.* Some anterior ethmoidal cells, numerous opposite left lachrymal bone. *t.* Turbinate fossa. *a.n.* Agger Nasi. *l.w.* Internal lateral wall of labyrinth continued anteriorly as the middle turbinate bone. *S.* Sphenoidal sinus. *p.p.p.* Posterior ethmoidal cells.

Plate 79.

HORIZONTAL SECTION, LOOKING UPWARD, MADE AT A LEVEL SO AS TO CUT THE APICES OF THE ANTRA.

n.c. Nasal cavity. *n.s.* Nasal septum. *A.* Apex of Antrum. *E.* Eyeball. *a.m.t.* Anterior extremity of middle turbinate. *p.m.t.* Posterior extremity of middle turbinate. *c.* Cells in middle turbinate. *a.a.a.* Some anterior ethmoidal cells. *p.p.* Posterior ethmoidal cells. *n.f.* Naso-frontal canal. *U.* Processus Uncinatus. *f.e.i.* Fissura ethmoidalis inferior, with free edge of superior turbinate toward the medium line. See plate 80.

Plate 80.



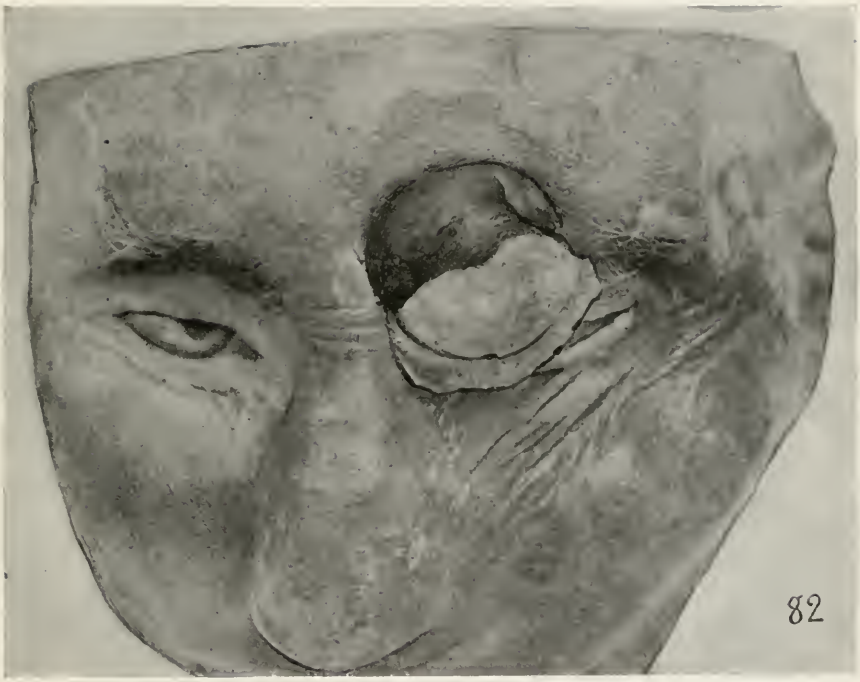
HORIZONTAL SECTION, OTHER HALF OF PLATE 79, LOOKING DOWNWARD. ARROW PASSES DOWN NASO-FRONTAL CANAL TO ANTRUM.

A. Antrum. *E*. Eyeball. *U*. Processus Uncinatus. *a.m.t.* Anterior portion of middle turbinate. *p.m.t.* Posterior portion of middle turbinate showing its horizontal aspect. *i*. Infundibulum. *B*. Bulla ethmoidalis on section. *m.m.* Middle meatus. *t*. Turbinate fossa. *c*. Cell in middle turbinate. *a.a.a.* Some anterior ethmoid cells. *p.p.p.* Some posterior ethmoid cells. *s*. Sinus of the Bulla ethmoidalis on the left side. *n.c.* Nasal cavity. *n.s.* Nasal septum.

Plate 81.

1. Showing line of Incision for Osteo-Plastic Operation, part of which is Concealed by the Eyebrow. It follows, in a Measure, the Natural Wrinkles of the Skin. 2. Incision for Approaching the Inferior Wall of the Frontal Sinus and Anterior Ethmoidal Cells.

Plate 82.



Showing Boneflap Turned Down, and Frontal Sinus Exposed. Posterior Wall of Sinus to be seen in the Background.

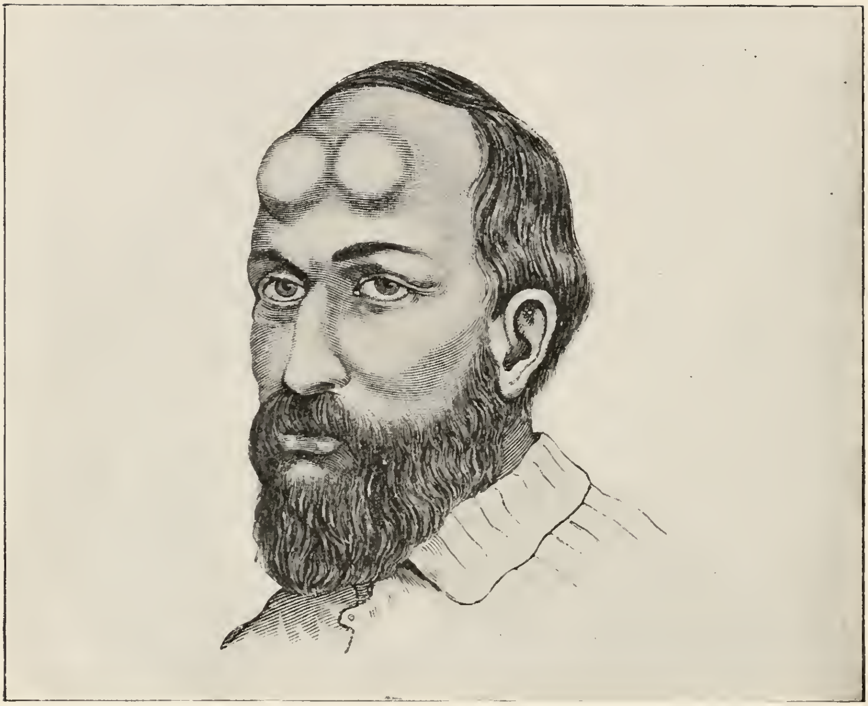
Plate 83.

Mucocele Involving Left Frontal Sinus. Eye Dislocated Downward and Outward. See Case 4.

Plate 84.

Combined Empyema of the Frontal Sinus, the Antrum of Highmore, and the Anterior Ethmoid Cells. See Case 3.

Plate 85.



Double Frontal Pneumatocele, Reported by Warren, Figured by Albert; Lehrbuch der Chirurgie.

Plate 86.

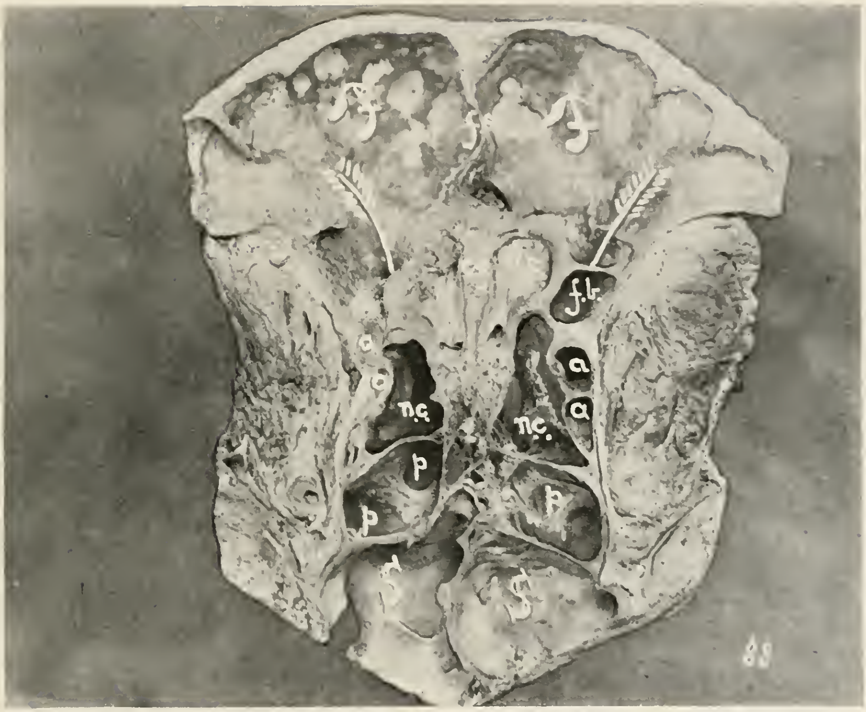
Mucocele. Albert, Lehrbuch der Chirurgie.

Plate 87.

HORIZONTAL SECTION JUST ABOVE THE LEVEL OF THE LAMINA CRIBROSA. UPPER HALF OF SECTION, LOOKING INTO LARGE FRONTAL SINUSES CONTAINING NUMEROUS SEPTA.

F. Frontal Sinus. *f.s.* Inter-frontal septum. *s.* Irregular septa. *f.b.* Frontal bulla. *a.a.a.* Anterior ethmoid cells. *p.p.p.* Posterior ethmoid cells. *S.* Sphenoidal sinus. *n.c.* Nasal cavity. See Plate 88.

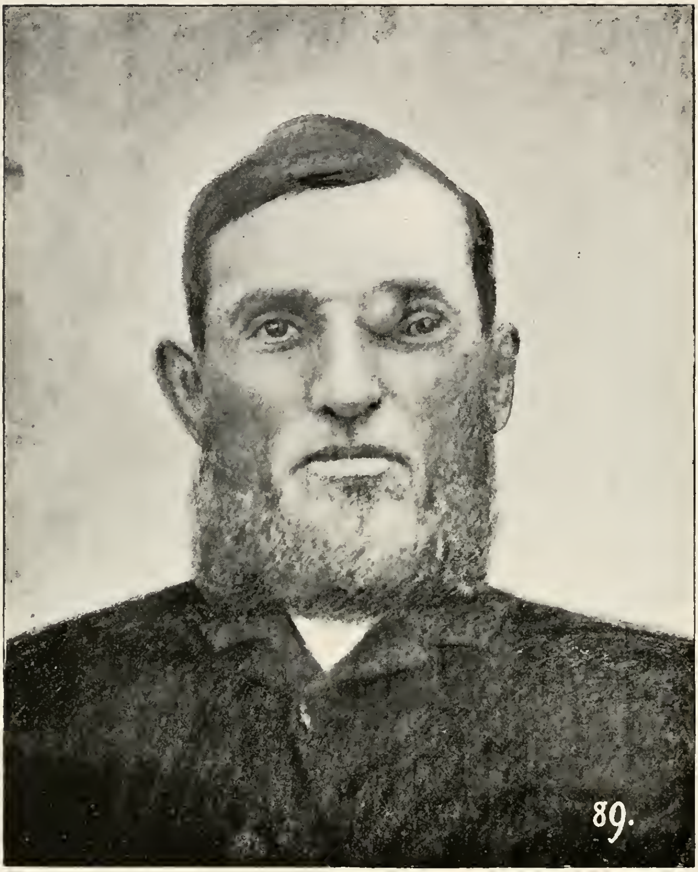
Plate 88.



Lower Half of Specimen Figured in Plate 87, Looking Downward, Showing the Floor of large Frontal Sinuses. Arrow through Ostium Frontale.

F. Frontal sinus. *f.s.* Inter-frontal septum. *l.c.* lamina cribrosa. *c.g.* Crista galli. *f.b.* Frontal bulla. *a.a.a.* Anterior ethmoid cells. *p.p.p.* Posterior ethmoid cells. *S.* Sphenoidal sinus. *n.c.* Nasal cavity.

Plate 89.



Dr. Pilcher's Case of Empyema of the Frontal Sinus.

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